

# **NATIONAL CORAL REEF INSTITUTE (NCRI)**

**Final Progress Report on NA04NOS4260065**  
**FY 2004, 2005, 2006 & 2007: June 1, 2004 to May 31, 2008**

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### **FORMAT for Annual Progress Report**

- A. Grant Number:** NA04NOS4260065
- B. Amount of Grant:** \$2,995,656
- C. Project Title:** National Coral Reef Institute
- D. Grantee:** Nova Southeastern University
- E. Award Period: From:** June 1, 2004 **To:** May 31, 2008
- F. Period Covered by this Report: From:** June 1, 2004 **To:** May 31, 2008
- G. Summary of Progress and Expenditures to Date:**

**1. Work Accomplishments: (as related to project objectives and schedule for completion)**

**a. Provide a brief summary of progress, including results obtained to date, and their relationship to the general goals of the grant;**

The primary objective of the National Coral Reef Institute (NCRI) is the assessment, monitoring, and restoration of coral reefs through basic and applied research and through training and education. All of these are in response to the Congressional directive for NCRI to protect and conserve coral reefs. Each proposed activity relates to this goal. The information in the Attachment (beginning on page 4) lists the proposed activities for this grant, followed in each case by the progress report for that item.

**b. Provide a brief summary of work to be performed during the next year of support, if changed from the original proposal; and indication of any current problems or favorable or unusual developments; and any other significant information pertinent to the type of project support by COP, or as specified by the terms and conditions of the grant.**

Any changes from the original proposal are noted in the Attachment. In addition, modifications, developments, and problems are described and discussed in each activity they pertain to (see the Attachment).

**2. Applications:**

**a. Publications, presentations, workshops;**

Research by NCRI personnel and research sponsored in part by NCRI have been presented at a number of national and international conferences. A variety of publications has been published or is in preparation. As of May 31, 2008, nine years of NCRI research have resulted in 99 peer-reviewed publications. There are also papers currently submitted to peer review publishers and a variety of technical

reports. Specific information is contained in the Attachment, enumerated by individual project.

**b. Applications to management or research;**

Descriptions of the applications to coral reef management and future research are detailed within the information contained in the responses listed in the Attachment.

**c. Data and/or information products;**

In addition to that listed in the Attachment, data and information for several projects are currently available on the recently expanded NCRI presence on the web at: <http://www.nova.edu/ocean/ncri/>.

**d. Partnerships established with other federal, state, or local agencies, or other research institutions (other than those already described in the original proposal).**

These are enumerated in the Attachment by project, as appropriate.

**3. Expenditures:**

**a. Describe expenditures scheduled for this period.**


Please refer to SF 269 & SF 272 filed with the NOAA Grants Office.

**b. Describe actual expenditures this period.**

Please refer to SF 269 & SF 272 filed with the NOAA Grants Office.

**c. Explain special problems, differences between scheduled and actual expenditures, etc.**

No special problems. In the subsequent year it is likely it will be necessary to rebudget certain items depending upon research needs. A further no-cost extension may be needed as well.

Prepared By:  Richard E. Dodge, Ph.D. August 13, 2008  
Signature of Principal Investigator Date

## ATTACHMENT

### Work Accomplishments

FY 2004, 2005, 2006, 2007 (June 1, 2004 to May 31, 2008) New and  
Continuing Projects

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This report deals with the work conducted during a NOAA award to NSU covering the period June 1, 2004 to May 31, 2008 or federal fiscal years FY 04, 05, 06, and 07.

## **1. The NCRI Monitoring Network: Monitoring and Assessment of Coral Reefs to Assess Impacts of Global Climate Change**

### **1.1 Work Accomplishments: (as related to project objectives and schedule for completion)**

#### **a. Provide a brief summary of progress, including results obtained to date, and their relationship to the general goals of the grant;**

As in the previous years, progress continued to build on ongoing achievements. Sites were re-visited in order to produce data required for the prediction of community trajectories. Data evaluation of previous site visits continues. The full number of sites as proposed for the project and as outlined in the proposal was achieved and re-visits were initialized.

Three sites in the Caribbean were evaluated. Work in Broward County continued and further publications describing geomorphology and habitat use by reefal benthos were published (Banks et al., Coral reefs of the USA, 2008). New work with regards to the history of the reefs was performed, and with the help of the U.S. Geological Survey (USGS) a drilling rig was built to obtain cores from the monitoring location. In Vieques, a complete re-evaluation of monitoring data was completed and the publication is in final preparation for print (Riegl et al., Journal of Coastal Research). At the monitoring sites in Roatan (Honduras) the image time-series was evaluated and a mathematical model for the maintenance of meta-populations structure of *Acropora cervicornis*, as well as the importance of the banks as refuges was evaluated. A paper was published (Rowlands et al., Journal of Spatial Science, 2008).

Work in the Pacific was further evaluated and algorithms for the evaluation of spatial patterns were developed. Work on reefs in the Mariana Islands came to a conclusion with a review of reef building in the Mariana Islands that includes the NCRI monitoring sites (Riegl et al., Coral Reefs of the USA, 2008). Reef building in American Samoa was reviewed and combined with monitoring information from other agencies to produce one submitted publication (Birkeland et al., Coral Reefs of the USA, 2008). Work in the Gulf of California was concluded and a final publication submitted (Halfar et al., Palaios). Also work in the Indian Ocean was concluded with a publication (Purkis et al., Coral Reefs, 2008).

Significant progress was continued in Middle Eastern monitoring sites where all reef areas in the southeastern Arabian Gulf were mapped, re-visited and a model of spatial and temporal dynamics was developed and submitted in publication (Riegl et al., Sedimentology). A model of coral population dynamics was also submitted (Riegl and Purkis, Ecological Modeling, submitted). A Ph.D. thesis that will utilize the existing monitoring sites and expand to sites in Fujairah and, possibly, Oman, was

continued.

In all mentioned sites, the core activities for the NCRI Monitoring Network were successfully achieved:

**Activity (1):** Obtain imagery of the study area.

**Activity (2):** Groundtruth remotely sensed maps, install monitoring transects, assess biodiversity.

**Activity (3):** Sample coral tissues for tissue-based stress indicators and coral diseases. The tissue samples were used for genetic analysis of population structure.

### **Milestones and Achievement Status:**

- *Complete data evaluation of additional monitoring sites accomplished in FY05.*

Achieved. All project personnel, techniques, and work-plan are in place.

- *Select any additional monitoring sites for FY06.*

Completed site evaluation in Pacific Ocean (Rota, Tinian, Saipan, Cabo Pulmo, Isla de la Paz).

Completed site evaluation in Indian Ocean (Diego Garcia).

Completed site evaluation in Arabian Gulf (Abu Dhabi and Qatar). Initiated repeat monitoring in Abu Dhabi. New sites installed in Fujairah in response to first hurricane hitting that coastline.

Completed site evaluation in the Caribbean (Broward County, Roatan, Vieques). Repeat monitoring in Vieques and Roatan to evaluate impact of 2005 bleaching event achieved publications in progress. No significant impacts found. Vieques experienced more bleaching than Roatan.

- *Obtain MOU with local management authority in first three monitoring localities.*

MOUs and/or permissions for the work were obtained from local authorities in the Commonwealth of the Northern Mariana Islands, Abu Dhabi, Fujairah, Honduras, Mexico, Diego Garcia. All work took place in collaboration with local management authorities and/or stakeholders.

- *Obtain remote-sensing imagery for those sites as needed.*

Ikonos imagery for Saipan, Rota, Tinian, Jebel Ali, and Roatan were acquired and evaluated. Quickbird imagery was acquired for Biscayne Bay, Roatan, and Ras Ghanada. Landsat imagery was acquired for Abu Dhabi and Broward County. Repeat imagery (Ikonos and Quickbird) for Vieques and Roatan were acquired.

- *Show tangible progress in data evaluation.*

Several publications have been published (*Journal of Spatial Ecology, Journal of*

*Geology, Sedimentology, Journal of Geology, Journal of Coastal Research, Coral Reefs*, several chapters in “*Coral Reefs of the USA*”) and more papers have been submitted (*Ecological Modeling*) .

- b. Provide a brief summary of work to be performed during the next year of support, if changed from the original proposal; and indication of any current problems or favorable or unusual developments; and any other significant information pertinent to the type of project support by COP, or as specified by the terms and conditions of the grant.**

The project is presently on target due to successes in previous years. Data evaluation will continue at sites in three oceans. All work required in the first phase of the project were successfully completed and publication of results is under way.

## **1.2 Applications:**

- a. Publications, presentations, workshops:**

### ***Presentations:***

None in 2008 yet (several accepted for the 11<sup>th</sup> ICRS)

### ***Publications in 08 that serve as proof-of-concept:***

Riegl, B, R.E. Dodge (2008) Introduction: A diversity of oceans, reefs, people, and ideas: a perspective of US coral research. In: Riegl B, Dodge RE (eds) *Coral Reefs of the USA*. Springer-Verlag, Dordrecht, 1-9

Riegl, B, S.J. Purkis, P. Houk, G. Cabrera, R.E. Dodge (2008) Geologic setting and geomorphology of coral reefs in the Mariana Islands (Guam and Commonwealth of the Northern Mariana Islands). In: Riegl B, Dodge RE (eds) *Coral Reefs of the USA*. Springer-Verlag, Dordrecht, 687-714

Banks, K.E., B.M. Riegl, V.P. Richards, B.E. Walker, K.P. Helmle, L.K.B. Jordan, J. Phipps, M. Shivji, R.E. Spieler, R.E. Dodge (2008) The reef tract of continental Southeast Florida (Miami-Dade, Broward, and Palm Beach Counties, USA). In: Riegl B, Dodge RE (eds) *Coral Reefs of the USA*. Springer-Verlag, Dordrecht, 125-172

Birkeland, C., P. Craig, D. Fenner, L. Smith, W.E. Kiene, B.M. Riegl (2008) Geologic setting and ecologic functioning of coral reefs in American Samoa. In: Riegl B., Dodge R.E. (eds) *Coral Reefs of the USA*. Springer-Verlag, Dordrecht, 737-762

Purkis, S.J., N.A.J. Graham, B. Riegl (2008) Predictability of reef fish diversity and abundance using remote sensing data in Diego Garcia (Chagos Archipelago). *Coral Reefs* 27:167-178

### ***Publications in press:***

Walker, B., B. Riegl, R.E. Dodge (2008) Mapping coral reef habitats: a combined technique approach. *Journal of Coastal Research* (in press)

Riegl, B., R. Moyer, R.E. Dodge, K. Kohler, B. Walker, D. Gilliam (2008) A tale of storms, bombs, and germs: Geomorphology and coral assemblage structure at Vieques (Puerto Rico) and St. Croix (U.S. Virgin Islands). *Journal of Coastal Research* (in press)

Riegl, B., S. Purkis (2008) Markov models for linking environments and facies in space and time (Recent Arabian Gulf, Miocene Paratethys). *IAS Special Publication* (in press)+

**b. Applications to management or research;**

Meaningful local coral reef management is ideally nested in an understanding of regional, or even world-wide, large-scale reef trajectories. A better understanding of these large-scale patterns will facilitate the selection of priorities that could possibly allow the development of evasive actions or countermeasures to avoid degradations that might otherwise be unexpected and maybe catastrophic. In a U.S. coral reef conservation context, the NCRI Monitoring Network will allow the ranking of different reef areas within the territorial waters according to their quality and threat level.

The NCRI Monitoring Network is directly applicable to the goals of the USCRTF and SEFCRI/SEFAST (Florida LAS).

**c. Data and/or information products;**

Image and metadata files are available and ready to be submitted to CoRIS database.

**d. Partnerships established with other federal, state, or local agencies, or other research institutions (other than those already described in the original proposal).**

A strong partnership with NOAA's National Centers for Coastal Ocean Science Mapping Group was established and data and information exchange was initiated. Also strong cooperation exists with the USGS St. Petersburg field office, with which data and information are being exchanged. A good working relationship exists with the CNMI Department of Fish and Wildlife, which results in data sharing. A partnership also was initiated with the United Arab Emirates Environment Agency and the Supreme Council for the Environment and Nature Reserves in Qatar.

**2. Expansion of the Coral Reef Evaluation and Monitoring Project (CREMP) to Southeast Florida (Collaborative with Florida DEP, FWC, and FMRI)**

**2.1 Work Accomplishments: (as related to project objectives and schedule for completion)**

**a. Provide a brief summary of progress, including results obtained to date, and their relationship to the general goals of the grant;**

This regional monitoring project continues on target to provide timely and important



information for state and county resource managers on reef status and trends to evaluate the success of management actions. This work assists in filling gaps in coverage of knowledge and monitoring of coral reef ecosystems in Florida and also the nation.

### **Milestones and Achievement Status for Third Year:**

- *Re-occupy the stations monitored in FY04.*

The 10 SECREMP sites established in 2003, and monitored in years 2003, 2004, 2005, and 2006 were successfully re-occupied in the summer of 2007. The 3 new sites established in 2006 in Martin County were successfully occupied and monitored in 2007.

- *Utilize designated protocols for data collections.*

The same protocols that are being used in the Florida Keys CREMP are being used in SECREMP to maintain consistency between programs and facilitate comparison between regions.

- *Analyze data.*

The 2007 data are currently being analyzed.

- *Report as needed.*

The final report discussing the 2007 effort is due to the Florida Fish and Wildlife Research Institute (FWRI) in June 2008.

- b. Provide a brief summary of work to be performed during the next year of support, if changed from the original proposal; and indication of any current problems or favorable or unusual developments; and any other significant information pertinent to the type of project support by COP, or as specified by the terms and conditions of the grant.**

In addition to the 10 SECREMP sites established in 2003, support was received from Florida DEP to add 3 sites in Martin County, Florida. These sites were chosen and installed in February 2006. These sites were successfully sampled in 2007 using the same sampling protocols.

## **2.2. Applications:**

- a. Publications, presentations, workshops;**

An abstract and oral presentation ("Higher Latitude Coral Reef Communities off Densely Populated Southeast Florida, USA") by D.S. Gilliam, S.L. Thornton, L.E. Fisher, and K. Banks on this project were submitted and presented as part of a high latitude reef session of the European Meeting of the International Society for Reef Studies in Cambridge, England, in September 2002.

An abstract and oral presentation (“Long-Term Monitoring of a High-Latitude Coral Reef System off Southeast Florida”) was given by D.S. Gilliam, K. Banks, C. Beaver, R. Dodge, L. Fisher, and W. Jaap as part of a session on reef management at the 10<sup>th</sup> International Coral Reef Symposium, Okinawa, Japan, 28 June – 2 July 2004.

An oral presentation (“Coral Condition on Southeast Florida Reefs (Dade, Broward, and Palm Beach Counties”) was given by D.S. Gilliam as part of the Joint Task Force Special Session: Responding to the Coral Reef Crisis: Improving Coral Reef Management in S. Florida. U.S. Coral Reef Task Force Meeting, December 4, 2004, Miami, Florida.

An invited lecture (“Long-Term Monitoring of a High-Latitude Coral Reef System off Southeast Florida”) was given by D.S. Gilliam at Florida Institute of Technology in Melbourne, Florida in May 2005.

An oral presentation (“Long-Term Monitoring of a High-Latitude Coral Reef System off Southeast Florida”) was given by D.S. Gilliam at the November 2005 Technical Advisory Committee meeting of the South East Florida Coral Reef Initiative, Land Based Sources of Pollution Focus Team.

An abstract was submitted and accepted as a poster presentation (Long-term monitoring of a high-latitude coral reef system off Southeast Florida, USA: a partnership between academia and resource management) to the 11<sup>th</sup> ICRS in Ft. Lauderdale, FL. July 2008.

**b. Applications to management or research;**

The purpose of SECREMP is the expansion of the Florida Keys CREMP to the SE Florida coral reefs. The partnership between NCRI, FWRI, and DEP expands local capacity for maintaining long-term monitoring sites which will assist in filling gaps in coverage of knowledge and monitoring of coral reef ecosystems nationwide. This work will also complement the goals of the National Coral Reef Institute’s Monitoring Network to monitor a minimum suite of parameters at sites in the network. This project also supports the goals and purpose of the USCRTF local action strategy in Florida, SEFCRI/LAS, primarily funded by Florida DEP and NOAA.

**c. Data and/or information products;**

Types of data include:

- a. Digital video of the station transects
- b. Percent cover of a number of important reef functional groups
- c. Coral disease presence

**d. Partnerships established with other federal, state, or local agencies, or other research institutions (other than those already described in the original proposal).**

NCRI's successful partnership with the Florida Department of Environmental Protection, Fish and Wildlife Research Institute, and Broward, Dade, and Palm Beach Counties continues.

### **3. Coral Reef Monitoring at Vieques, Puerto Rico and St. Croix, United States Virgin Islands**

#### **3.1 Work Accomplishments: (as related to project objectives and schedule for completion)**

##### **a. Provide a brief summary of progress, including results obtained to date, and their relationship to the general goals of the grant;**

In summer 2006, NCRI successfully re-occupied all 18 Vieques sites and 6 St. Croix sites. In the past NCRI had some difficulty obtaining access to previously generated data. NCRI has now been granted permission to use previously generated data, and the 2006 effort will be compared to the 2001 effort to provide a robust statement on the current status of the reef system off the east end of Vieques and will be a powerful tool to document change. Data will be made available to the government of Puerto Rico, the U.S. Fish and Wildlife Service, and NOAA through complete data sets, reports, and publications. NCRI has discussed the Vieques efforts with the NOAA Office of Response and Restoration in preparation of their 2007 work. The St. Croix USVI work will specifically compliment the USVI monitoring effort currently conducted by the University of the Virgin Islands (UVI). The similar image based methods of the two programs will allow data sharing and comparisons to be straightforward and meaningful.

#### **Milestones and Achievement Status for Third Year:**

- *Submit FOIA request to obtain our previous 2001 baseline assessment data from Navy.*

An FOIA was not needed because of the transfer of all U.S. Navy owned data to U.S. FWS. Previous data was requested from U.S. FWS and received. Hence we were able to use the 2001 baseline assessment data for future publications and research.

- *Re-occupy, as schedule permits, previously established permanent sites in Vieques. (This may be shifted to FY05 if necessary.)*

Site re-occupation was completed in July 2006. All 18 Vieques sites were successfully sampled.

- *Re-occupy, as schedule permits, previously established sites in St. Croix as possible. (This may be shifted to FY05 if necessary.)*

Site re-occupation was completed in August 2006. All 6 St. Croix sites were successfully sampled.

- *Employ similar methods utilized for the 2001 baseline assessment.*

The same methods were used in 2006 when the sites were re-occupied.

- *Reduce and analyze data.*

Data is currently being reduced and analyzed.

- b. Provide a brief summary of work to be performed during the next year of support, if changed from the original proposal; and indication of any current problems or favorable or unusual developments; and any other significant information pertinent to the type of project support by COP, or as specified by the terms and conditions of the grant.**

This project was included in the most current NCRI proposal (for FY07, 08, and 09). The next field effort is tentatively scheduled for 2008. The infrastructure on Vieques Island has changed since the U.S. Navy has left, therefore, the scope of work may be modified due to the increased challenges of working on Vieques.

This field effort will likely need to be curtailed due to funding constraints imposed in FY07 and FY08.

### **3.2 Applications:**

- a. Publications, presentations, workshops;**

Publications utilizing the 2006 data are in progress and a poster has been accepted for the 11<sup>th</sup> ICRS in July 2008.

- b. Applications to management or research;**

An integral part of NCRI's mission is to lead and participate in coral reef monitoring programs. NCRI is currently managing several southeast Florida reef system monitoring programs (see Section 2, above) that include sites in Miami-Dade, Broward, Palm Beach, and Martin Counties. It is appropriate that NCRI expand its monitoring activities into other U.S. territorial coral reef systems. Vieques, P.R. and St. Croix, U.S.V.I. are logical areas for NCRI monitoring efforts due to current heightened interests and NCRI's recent experience in these areas.

From the 1940s to 2003, the U.S. Navy utilized the eastern end of Vieques Island as a training facility and bombing range. In 2003, the Navy gave up control of these facilities and the land and marine resources. The terrestrial resources are now managed by the U.S. Fish and Wildlife Service which has incorporated the area into the Vieques Wildlife Refuge, creating the largest such refuge in the Caribbean. The marine resources are managed by the Puerto Rico Department of Natural and Environmental Resources (DNER). This project has been developed after consultation with DNER, who will be the beneficiaries of the data obtained during the project. With the ending of Naval operations and the creation of a large wildlife refuge, there is an ever-increasing need to evaluate the current status and monitor the condition of the coral reef resources of Vieques.

Protocols for the VSTXMP are complementary with those of the NCRI Monitoring Network program. The VSTXMP, however, accomplishes investigations in greater

detail, finer scale, and deeper depth for some sites. Hence this research serves to provide value-added, stand-alone ecological data and information, which enhances the NCRI Monitoring Network results and utility.

**c. Data and/or information products;**

Types of data include:

- a. Digital video of the station transects
- b. Percent cover of a number of important reef functional groups
- c. Coral disease presence

**d. Partnerships established with other federal, state, or local agencies, or other research institutions (other than those already described in the original proposal).**

NCRI intends for this to be a long-term monitoring program either annual or bi-annual and will maintain communications with the U.S. Fish and Wildlife Service, Puerto Rico Department of Natural Resources, and St. Croix reef resource managers.

**4. Restoration Design and Post-Restoration Monitoring Project (Collaborative with Broward County; Completed.**

**4.1 Work Accomplishments: (as related to project objectives and schedule for completion)**

**a. Provide a brief summary of progress, including results obtained to date, and their relationship to the general goals of the grant;**

One hundred-sixty small (1.13 m) ReefBalls<sup>®</sup> were organized into 40, 4-module quads. To examine the role of substrate on coral settlement and mortality, each ReefBall in a quad had settlement plates with one of four treatments: iron, limestone, coral transplants, or plain concrete. To examine effects of fish assemblages on coral settlement and growth, quads were further divided into four treatments of structural complexity by filling the central void space of the ReefBalls with differently sized fill (empty, small, mixed, large). After 24 months, empty ReefBalls had lower total fish abundance and richness than the treatments with fill ( $p < 0.05$ , ANOVA), which did not differ from each other. Interestingly, corals were also lower in abundance on the outer surface of empty reef balls than on those with fill ( $p < 0.03$ ). Corals tended to be higher on limestone treated settlement plates (12) than other substrate treatments (6 each) ( $p < 0.08$ ). *Porites* spp. were the predominant corals recorded (69.9%) followed by *Agaricia* spp. (18.2%), and *Diploria* spp. (9.5%). *Montastrea cavernosa* and *Meandrina meandrites* were used for transplantation. 100% of the *M. cavernosa* maintained or increased their tissue surface area, whereas, 72.5% of the *M. meandrites* transplants showed varying degrees of tissue mortality. An attempt to get additional funding for this project from the Florida Fish and Wildlife Conservation Commission was not successful.

**b. Provide a brief summary of work to be performed during the next year of**

**support, if changed from the original proposal; and indication of any current problems or favorable or unusual developments; and any other significant information pertinent to the type of project support by COP, or as specified by the terms and conditions of the grant.**

Data collection has been completed for this project as funded and the main body of data analysis is also completed. A final report was submitted to Broward County. A Ph.D. dissertation, scientific publication, and presentation at a scientific meeting will be accomplished in the next 12 months. If we procure additional funding, data collection will resume as well.

## **4.2 Applications:**

### **a. Publications, presentations, workshops;**

#### ***Presentations:***

Fahy, E.G., R.E. Dodge, D.P. Fahy, T.P. Quinn, D.S. Gilliam, and R.E. Spieler. (In press.) Growth and survivorship of scleractinian coral transplants and the effectiveness of plugging core holes in transplant donor colonies. 10<sup>th</sup> International Coral Reef Symposium, Okinawa, Japan. June 28 – July 2, 2004.

Quinn, T.P., E.G. Fahy, J.L. Robinson, R.E. Dodge, and Richard E. Spieler. 2004. Multivariate hypotheses-based coral reef restoration study using artificial reefs with varying coral transplants and fish refuges. 39<sup>th</sup> European Marine Biology Symposium - Genoa, 21-24 July 2004.

Quinn, T.P., E.G. Fahy, J.L. Robinson, R.E. Dodge, and Richard E. Spieler. 2004. Hypotheses-based restoration study for mitigation of a S.E. Florida U.S.A. coral reef damaged by the grounding of a nuclear submarine. 10<sup>th</sup> International Coral Reef Symposium, Okinawa, Japan. June 28 – July 2, 2004.

Quinn, T.P., E.G. Fahy, J.L. Robinson, R.E. Dodge, R.E. Spieler. 2004. Mitigation Of A S.E. Florida U.S.A. Coral Reef Damaged By The Grounding Of A Nuclear Submarine; Results Of A Hypotheses-Based Restoration Study. 1st. National Conference on Ecosystem Restoration. 2004.

Quinn, T.P., Fahy, E.G., Dodge, R.E., Spieler, R.E. 2005. Mitigation of a S.E. Florida (U.S.A.) coral reef damaged by the grounding of a nuclear submarine; results of a hypotheses-based, multivariate restoration study. ASLO Summer Meeting, Santiago de Compestela, Spain. June 19-24, 2005.

#### ***Publication:***

Fahy, E. G., Dodge, R. E., Fahy, D. P., Quinn, T. P., Gilliam, D. S., and R. E. Spieler. 2006. Growth and survivorship of scleractinian coral transplants and the effectiveness of plugging core holes in transplant donor colonies. Proc. 10<sup>th</sup> International Coral Reef Symposium, 1657-1664.

### **b. Applications to management or research;**

The knowledge required for coral reef restoration is lacking. Currently, “green thumb” or “best guess” approaches are used. The results of this experimental, hypothesis-driven study highlighted the interaction of biotic and abiotic ecosystem components and indicated the need for a broad, ecosystem approach to restoration rather than a myopic single-organism approach. The species-specific differences in transplant growth and mortality indicate that species selection must be an important consideration in future coral reef restoration efforts. The unanticipated species-specific difference in mortality also indicates the need for an adaptive-management approach to restoration

**c. Data and/or information products;**

None

**d. Partnerships established with other federal, state, or local agencies, or other research institutions (other than those already described in the original proposal).**

The original partnership has been maintained with Broward County Environmental Protection Department (previously named Broward County Department of Planning and Environmental Protection).

**5. Increasing Fish Assemblage Richness and Abundance on Concrete Artificial Reefs Used in Coral-Reef Restoration with a Novel Invertebrate Recruiting Substrate.**

**5.1 Work Accomplishments: (as related to project objectives and schedule for completion)**

**a. Provide a brief summary of progress, including results obtained to date, and their relationship to the general goals of the grant; and**

The purpose of this study is to enhance artificial reefs used in coral-reef restoration by the addition of a novel substrate for invertebrate recruitment with the intention that this will result in an increased abundance and richness of the reef-associated fishes.

We deployed 32 ReefBalls™ in Broward County, FL with internal structure (concrete block) and invertebrate substrate treatments (AIS) or without either (controls). Quarterly fish census and six-week invertebrate collections were accomplished over two years, (2005-2007). In the most recent census, fish richness and abundance was highest on modules with internal structure and AIS. Unlike bare modules without AIS, those with AIS were colonized by the major phyla of marine invertebrates within two weeks of deployment.

Twenty-nine families and 112 species of fish were identified. An apparent preferential selection of treatment type was noted for several species. Larger reef fish such as *Gymnothorax miliaris*, *Gymnothorax vicinus*, and *Lachnolaimus maximus* associated with treatments that offered internal refuge (blocks). In addition, there were often more *Balistes capriscus*, *Acanthurus chirurgus*, *Lutjanus synagris* and *Haemulon melanurum* on these modules. No significant difference (GLM) was found

between treatments with internal refuge with or without substrate; however, the combination of internal refuge and invertebrate substrate showed the highest abundance for these species. In contrast, *Stegastes partitus* and *Thalassoma bifasciatum* were significantly more abundant on modules with invertebrate substrates than on block alone or control. This study provides insight into the effects of invertebrate refuge on fish assemblages, highlights the value of artificial substrate design in the establishment of a diverse fish community, and ultimately may provide a unique method for enhancing coral reef restoration efforts.

- b. Provide a brief summary of work to be performed during the next year of support, if changed from the original proposal; and indication of any current problems or favorable or unusual developments; and any other significant information pertinent to the type of project support by COP, or as specified by the terms and conditions of the grant.**

Fieldwork is completed. Laboratory identification of the invertebrates is proceeding and anticipated to continue for the coming year.

## **5.2 Applications:**

- a. Publications, presentations, workshops;**

Kilfoyle, K., R. Dodge, R. Spieler (2006) An ecosystem restoration approach to coral reef repair: experimental design. Presentation at RRWG Meeting & Workshop – Bolinao, Bolinao Marine Laboratory, Marine Science Institute, University of the Philippines. 21 -25 August 2006.

Robinson, J., L. Robinson, B. Buskirk, R. Spieler. Increasing the fish assemblage on concrete modules used in coral-reef restoration with the addition of a novel invertebrate recruiting substrate. Poster presentation at AAUS annual mtg. March 2007.

Robinson, J., L. Robinson, B. Buskirk, R. Spieler. Effects of a Novel Invertebrate Substrate on Fish Assemblages Associated with Concrete Modules. Poster accepted for ICRS 2008.

Kilfoyle, K., M.A. Rangel, R. Dodge, R. Spieler. Coral Reef Restoration: Standardized Module Intervention and Monitoring Program in Mexico, Preliminary Results. Poster accepted for ICRS 2008.

- b. Applications to management or research;**

Full restoration of a damaged coral reef should, by definition, include the restoration of the pre-impact faunal community. However, to date, most restoration efforts have had a myopic focus, concentrating on limited target organisms, for example, returning coral populations, usually by transplant, and fish populations, by providing artificial refuge. Normally these restoration efforts do not make specific attempts to increase the non-coral invertebrate assemblages. The invertebrate assemblages are, however, a critical part of the coral ecosystem and form a critical forage base for the majority of coral reef fishes. If the artificial substrate for invertebrates results in an increased abundance and richness of the reef-associated fishes in this study, it would not only



provide an ancillary technique for enhancing fish assemblages on artificial reefs, it would also provide an impetus to more ecosystem-based restoration research.

**c. Data and/or information products;**

None.

**d. Partnerships established with other federal, state, or local agencies, or other research institutions (other than those already described in the original proposal).**

Preliminary data from this project has served as an impetus for a similar restoration research study in Puerto Morales Mexico funded by the World Bank GEF.

**6. Establishment and Maintenance of a Coral Nursery (Collaborative with Broward Co. DPEP and NFWF; Continuing with collaboration from BC DPEP)**

**6.1 Work Accomplishments: (as related to project objectives and schedule for completion)**

**a. Provide a brief summary of progress, including results obtained to date, and their relationship to the general goals of the grant;**

An agreement with National Fish and Wildlife Foundation (NFWF) was signed on January 22, 2001. The agreement was for 2 years with a start date of January 1, 2001 and an end date of December 31, 2002. A final programmatic report was submitted to NFWF on January 31, 2003. Although the NFWF funding has ended, the project partners (NSU OC, Broward County Environmental Protection Department [BC EPD], and Ocean Watch Foundation [OWF]) have agreed to continue this successful and worthwhile project. The effort has been reduced slightly. Based on the availability of project partners, Coral Nursery dive days are scheduled monthly in the spring and summer months (May-September) rather than year round.

From June 2001 through December 2002 (NFWF funded period), the NCRI research vessel, *Researcher*, and the BC EPD research vessel, *Monitor*, were used for 34 field days. These days included collecting and transplanting corals, locating and tagging control corals, and monitoring the transplanted and control corals. During this period, over 300 loose/dislodged coral colonies were transplanted to the two artificial reefs that make up the Nursery. The size, species, and health of each of these corals were recorded at the time of transplantation. In addition, the corals were tagged and imaged with a camera attached to a framer. Thirty-two control corals were mapped and tagged and imaged in the same way as the transplanted corals. Information on colony size, species, and health were recorded. All of these corals are located on natural reef near the Coral Nursery site. All of the transplanted and control corals were monitored quarterly through January 2004. Monitoring includes recording general health and stability and taking planar images of each colony to be used for growth analysis. An analysis and comparison of health and growth of the transplanted corals against the control corals will continue through the project.

From March 2005 through February 2006 (BC DPEP and NCRI funded period), two monitoring trips were completed. Project partners were not available for CNP collection trips during this time period. In 2006, stony corals from the Nursery were planned to be used as donor colonies to help restore a ship grounding site near the Nursery. The use of these Nursery corals as a source of donor corals for reef restoration is the ultimate goal of the CNP. Working with the Florida Fish and Wildlife Research Institute (FWRI), the scope for this work was drafted in late 2005 for a project start in summer 2006.

In addition to creating a nursery for loose corals, this project was designed to provide community outreach and use volunteer divers to assist with coral collection, data collection, and transplantation. The community-based volunteer divers participating in the project are members of the Ocean Watch Foundation (OWF) ([www.oceanwatch.org](http://www.oceanwatch.org)). OWF is an active volunteer environmental group in Broward County and both NCRI and BC EPD have worked with them on other projects. The Coral Nursery Project was introduced to the OWF leaders in early March 2001, and they agreed to support the project both in terms of utilizing their members as volunteer divers and utilizing their leader as the contact person between the volunteer divers and NCRI. The NSUOC, BC EPD, and OWF relationship has been positive and will continue.

Four presentations on general coral reef ecology, Broward County reef ecology and geology, and the Coral Nursery Project were given to members of Ocean Watch. A productive question-and-answer session followed each of the presentations. These presentations will continue to be repeated on a regular basis for OWF members and Nursery volunteer divers. Additionally, coral reef ecological discussions and Coral Nursery techniques are discussed the morning of and during coral collection and transplantation trips. Laminated coral identification review sheets are also used on all Coral Nursery dives to assist volunteers in identifying Broward County coral species.

Another fortuitous means of community outreach came as the result of a number of newspaper articles being published about this project. Four local newspapers ran feature stories (and one supportive editorial), one of which was picked up in Knight-Ridder Newspapers syndication. A short segment was also produced for a local public school television series.

- b. Provide a brief summary of work to be performed during the next year of support, if changed from the original proposal; and indication of any current problems or favorable or unusual developments; and any other significant information pertinent to the type of project support by COP, or as specified by the terms and conditions of the grant.**

Discussion with the Florida Wildlife Research Institute (FWRI) of the Florida Fish and Wildlife Commission (FWC) finalized an effort in 2006 which included the use and monitoring of corals from the Nursery as a source of donor colonies. Colony relocation was accomplished in January 2007. Fifty stony coral colonies were moved from the Nursery to a grounding site offshore Broward County, Florida. This is an exciting addition to the Coral Nursery project because it was the first time colonies of opportunity from the Nursery were used in a restoration project. This is the ultimate

goal of the Coral Nursery Project. Monitoring of the 50 transplants was completed in January 2008. Discussions with FWRI continue for the use of additional Nursery colonies and continued maintenance of the Nursery.

## **6.2 Applications:**

### **a. Publications, presentations, workshops;**

Four presentations on general coral reef ecology, Broward County reef ecology and geology, and the Coral Nursery Project were given at NSU OC to members of our volunteer groups (OWF) and other interested people. Presentations on the Coral Nursery Project were also made to three other organizations, the South Florida Women Divers, South Florida Divers, and the Palm Beach County Reef Research Team. A productive question-and-answer session followed each of the presentations. Although the NFWF funding for this project has ended, NSUOC and DPEP are planning to continue these presentations on a yearly basis.

An abstract and oral presentation (“The Use of Coral Nurseries as a Coral Reef Management Tool Off the Coast of Southeast Florida, USA,” by J.A. Vernacchio and D.S. Gilliam) on this project were submitted and presented as part of a reef management session of the European Meeting of the International Society for Reef Studies in Cambridge, England, in September 2002.

A related abstract and presentation (“Higher Latitude Coral Reef Communities Off Densely Populated Southeast Florida, USA,” by D.S. Gilliam, S.L. Thornton, L.E. Fisher, and K. Banks) were also submitted and presented for this meeting.

An abstract and oral presentation (“The Coral Nursery Project: An Integrated Approach to Coral Reef Restoration Off the Coast of Southeast Florida, USA”) was given by R.P. Moyer for J.A. Vernacchio and D.S. Gilliam as part of a session on tourism, conservation, and education at the symposium “Coral Reefs: United for Conservation” in Cayo Coco, Cuba, September 16–20, 2002.

An abstract, oral presentation, and proceedings paper (“Coral of Opportunity Survivorship and the Use of Coral Nurseries in Coral Reef Restoration”) was given by J.A. Monty (nee Vernacchio) and D.S. Gilliam as part of a session on reef restoration at the 10<sup>th</sup> International Coral Reef Symposium, Okinawa, Japan, 28 June – 2 July 2004.

Masters’ research theses - Jamie Monty. 2006. Coral of Opportunity Survivorship and the Use of Coral Nurseries in Coral Reef Restoration.

### **b. Applications to management or research;**

CNP success is measured in the importance of the reef restoration information gathered, which benefits the management community, and in the importance of community outreach and education provided through volunteer involvement. CNP supports NCRI goals and NCRI’s involvement with the USCRTF and the SEFCRI by promoting wise management, sustainable use, and restoration of coral reef ecosystems while working with local government and volunteer groups. Although

original funding provided by the NFWF and the NOAA Fisheries Community-Based Restoration Program has ended, NCRI and its local partners (BCEPD and OWF) are committed to continuing this valuable project.

**c. Data and/or information products;**

Types of data include:

- a. Quadrat images of the transplanted corals
- b. Survivorship data (dead or alive)
- c. Colony size data (area cm<sup>2</sup>)

This project's resultant scientific data and community outreach response will be shared with the broader coral reef management and research community through publication in journals and presentation at national and international meetings and conferences

**d. Partnerships established with other federal, state, or local agencies, or other research institutions (other than those already described in the original proposal).**

NFWF was partner for the first 2 years of the project. A very positive and productive relationship with Broward County Environmental Protection Department and the Ocean Watch Foundation will continue. The Florida Wildlife Research Institute (FWRI) of the Florida Fish and Wildlife Commission (FWC) is a new partner through the use of corals from the nursery in a restoration effort completed in January 2007.

**7. Comparison of Fish at Selected Artificial Reefs and Natural Substrate in Southeast Florida (Collaborative with Broward Co. DPEP; Continuing)**

**7.1 Work Accomplishments: (as related to project objectives and schedule for completion):**

**a. Provide a brief summary of progress, including results obtained to date, and their relationship to the general goals of the grant:**

*Note:* Because Projects 7 and 8.1 and their resources are tightly interrelated, reports on these two projects are similar.

The current work involves a visual fish census of hard bottom neighboring vessel-reefs in 70 to 150 m of water offshore Broward County using a remotely operated vehicle (ROV). This research has suffered some equipment and personnel problems over the last 12 months. The ROV broke down repeatedly; when it was functioning (or assumed to be functional), the pilot was unavailable or there was inclement weather. Nevertheless, work to date does confirm both the feasibility of the ROV

census technique as well as depauperate ichthyofauna off Broward County on the flat hardbottom area in the 70–150 m depth range.

- b. Provide a brief summary of work to be performed during the next year of support, if changed from the original proposal; and indication of any current problems or favorable or unusual developments; and any other significant information pertinent to the type of project support by COP, or as specified by the terms and conditions of the grant.**

We continued with the non-destructive, visual fish census using a remotely operated vehicle (ROV). However we altered the transect methodology from making transects 300 m from vessel-reefs to making East-West transects between the third reef (30 m water depth) to the vessel reefs. The third reef is the closest complex hard bottom to the vessel-reefs and it now appears any aggregation to the vessel reefs would likely come from the third reef.

The problems we were having with the ROV equipment was reduced by switching subcontractors. We continued to have problems with scheduling and weather.

Funding support ended from NOAA in August 2006 and data collection was completed and a final report submitted in that month. We anticipate submitting the results for publication in the next 12 months.

## **7.2 Applications:**

**a. Publications, presentations, workshops;**

Bryan, D.R., P.T. Arena, and R.E. Spieler. (2004) Preliminary comparisons between reef fish assemblages on vessel-reefs and natural substrate in depths of 70-95 m. 57<sup>th</sup> Gulf and Caribbean Fisheries Institute. Tampa FL.

Arena, P., L. Jordan, R.E. Spieler. (2007) Fish assemblaged on sunken vessels and natural reefs in SE Florida, USA. *Hydrobiologia*, 580:157-171.

Bryan, D.R. Reef fish communities on natural substrate and vessel-reefs along the continental shelf of southeastern Florida between 50 and 120, depth. MS Thesis. Nova Southeastern University, Oceanographic Center. 131 pp.

**b. Applications to management or research;**

This is the continuation of the first comprehensive survey of the coral reef fishes of Broward County. As such, it will provide a baseline database with which to compare future change in the local fish assemblage in response to anthropogenic or natural causes. Proper understanding and management of fish resources cannot be undertaken without informed knowledge of the abundance and diversity of fish populations and communities. This study provides information to help scientists and resource managers.

**c. Data and/or information products;**

None.

- d. Partnerships established with other federal, state, or local agencies, or other research institutions (other than those already described in the original proposal).**

There have been no additions to our original partnership with NOAA/NMFS and the Florida Fish and Wildlife Conservation Commission.

## **8. Fish Censuses of Southeast Florida**

### **8.1 Survey of the Marine Fishes of Southeast Florida (Collaborative with NOAA NMFS; Continuing)**

#### **8.1.1 Work Accomplishments: (as related to project objectives and schedule for completion)**

- a. Provide a brief summary of progress, including results obtained to date, and their relationship to the general goals of the grant; and**

The current work involves a visual fish census of vessel-reefs in 70 to 150 m of water offshore Broward County using a remotely operated vehicle (ROV). This research has been plagued with equipment and personnel scheduling problems over the last 36 months. The ROV broke down repeatedly; when it was functioning (or assumed to be functional), the pilot was unavailable or there was inclement weather. A total of 21 h of ROV surveys have been completed to date and confirms the feasibility of the ROV census technique. In contrast to neighboring hardbottom the vessel-reefs have an abundant and diverse fish community and indicate such artificial reefs may be important tools for the management of fish assemblages at the depths of this study off Broward County.

- b. Provide a brief summary of work to be performed during the next year of support, if changed from the original proposal; and indication of any current problems or favorable or unusual developments; and any other significant information pertinent to the type of project support by COP, or as specified by the terms and conditions of the grant.**

The field portion of the surveys is complete. Funding support continues until June 2007. Given the extensive problems encountered with weather, equipment, subcontractors, and scheduling we do not intend on requesting additional funding for this project. The work will be completed and a manuscript detailing the findings will be prepared and submitted for publication.

### **8.2 Nearshore Hardbottom Fishes of Broward County (Collaboration with Broward County, Continuing)**

#### **8.2.1 Work Accomplishments: (as related to project objectives and schedule for completion)**

- a. Provide a brief summary of progress, including results obtained to date, and**

**their relationship to the general goals of the grant.**

During the summer of 2001, a project inventorying the fishes on the nearshore edge of the first reef tract of Broward County was initiated as a project of opportunity, initially to be completed in FY 2002, but was extended to 2007. This study was undertaken to examine the fish assemblages on the nearshore hardbottom area adjacent to a 15-km stretch of beach in Broward County, FL with an eye to the potential effects of a proposed beach renourishment. Four-hundred fish counts were accomplished and two reports prepared and delivered to Broward County during the past year.

- b. Provide a brief summary of work to be performed during the next year of support, if changed from the original proposal; and indication of any current problems or favorable or unusual developments; and any other significant information pertinent to the type of project support by COP, or as specified by the terms and conditions of the grant.**

In the coming 12 months we will re-census the inshore fish assemblages along a 15-km stretch of Broward County shoreline potentially impacted by beach renourishment using nondestructive techniques, i.e., visual censusing. The results will be compared to the results obtained with previous censuses (2001, 2003, 2004, 2005, 2006, and 2007) of the same sites. Beach renourishment has been completed. This will allow a second post-impact assessment and a pre/post impact comparison. We will also compare the fish assemblages on mitigation reefs (limestone boulders) to adjacent natural reef. A report to Broward County will be prepared. We anticipate this work will generate at least one presentation at a scientific meeting in the coming year.

**12.2 Applications:**

- a. Publications, presentations, workshops;**

Jordan, Lance K.B., D.S. Gilliam, R.L. Sherman, P.T. Arena, F.M. Harttung, R. Baron, and R.E. Spieler (2002) Spatial and temporal recruitment patterns of juvenile grunts (*Haemulon* spp.) in south Florida. Proc. Annual Gulf Caribb. Fish. Instit. 322-336.

Baron, Robert M., L.K.B. Jordan, and R.E. Spieler (2004) Characterization of the marine fish assemblage associated with the nearshore hardbottom of Broward County Florida, USA. Estuar Coast Shelf Sci. 60: 431-443.

Jordan, L.K.B., and R.E. Spieler. (2004) Implications of natural variation of fish assemblages to coral reef management. Nat'l Conference on Ecosystem Restoration .Orlando FL

Sherman, R.L., P.T. Arena, T.P. Quinn, and R.E. Spieler (2005) Structural attributes of artificial reefs and associated fish assemblages. to be presented at the annual meeting of the Fisheries Society of the British Isles.

Jordan, L.K.B., and R.E. Spieler (2006) Implications of natural variation of fish assemblages to coral reef management. Proc. 10<sup>th</sup> Int. Coral Reef Sym. 1391-1395.

**b. Applications to management or research;**

Our results provide critical baseline data for determining the effects of beach renourishment on nearshore fishes in Broward County. In addition, the large variation in fish abundance and species richness noted between years has widespread implications for determining potential anthropogenic change in fish assemblages (e.g., caused by beach renourishment). For example, had beach renourishment proceeded as originally scheduled, the natural variation between years might have, wrongly, been attributed to the renourishment. Clearly, temporal as well as spatial variation must be considered in establishing a baseline database.

**c. Data and/or information products;**

All the collected data was submitted to Broward County in Excel and Acrobat formats.

**d. Partnerships established with other federal, state, or local agencies, or other research institutions (other than those already described in the original proposal).**

None in addition to our original partners Broward County Environmental Protection Department (previously named Broward County Department of Planning and Environmental Protection) and Coastal Planning and Engineering Inc.

**9. Multivariate Examination of Spatial Patterns of Grunt (Haemulidae) Recruitment (Continuing)**

**9.1 Work Accomplishments: (as related to project objectives and schedule for completion)**

**a. Provide a brief summary of progress, including results obtained to date, and their relationship to the general goals of the grant; and**

The study site is offshore Broward County, Florida. In a series of overlapping, hypothesis-driven substudies, the study examines the roles of refuge, water depth, predation, food quantity/quality, and interspecific competitive exclusion on grunt recruitment. The substudies examine natural distribution and potential distribution determinants as well as experimentally verifying potential determinants using artificial reef modules and removal/replacement studies.

NCRI researchers have already accumulated a database in excess of 1500 fish counts on natural reef and 1500 counts on artificial reef. This database provides important comparative information for determining if the experimental controls of the new study are representative, or atypical of the natural environment at the study site.



During 2005-2006, the experiment modules were deployed and all the field data was collected.

- b. Provide a brief summary of work to be performed during the next year of support, if changed from the original proposal; and indication of any current problems or favorable or unusual developments; and any other significant information pertinent to the type of project support by COP, or as specified by the terms and conditions of the grant.**

In the coming year identification of the collected juvenile grunts will be completed and the data will be analyzed and a manuscript detailing the findings will be prepared and submitted for publication. The results will also be presented, in part, at the 11<sup>th</sup> ICRS in July 2008.

## **8.2 Applications:**

### **a. Publications, presentations, workshops;**

Jordan, Lance K.B., D.S. Gilliam, R.L. Sherman, P.T. Arena, F.M. Harttung, R. Baron, and R.E. Spieler. (2002) Spatial and temporal recruitment patterns of juvenile grunts (*Haemulon* spp.) in south Florida. Proc. Annual Gulf Caribb. Fish. Instit. 322-336.

Arena, P.T., L.K.B. Jordan, R.L. Sherman, F.M. Harttung, and R.E. Spieler. (2002) Presence of Juvenile Blackfin Snapper, *Lutjanus buccanella*, and Snowy Grouper, *Epinephelus niveatus*, on Shallow-water Artificial Reefs. Proceedings of the 55th Gulf and Caribbean Fisheries Institute 55: 700-712

Baron, Robert M., L.K.B. Jordan and R.E. Spieler. (2004) Characterization of the marine fish assemblage associated with the nearshore hardbottom of Broward County Florida, USA. Estuar Coast Shelf Sci. 60: 431-443.

Jordan, L.K.B. and R.E. Spieler. (2004) Implications of natural variation of fish assemblages to coral reef management. Nat'l Conference on Ecosystem Restoration, Orlando, FL.

Jordan, Lance K.B., D.S. Gilliam and R.E. Spieler. (2005) Effects of module spacing on the formation and maintenance of fish assemblages on artificial reefs. Journal of Experimental Marine Biology. 326, 170-186.

Jordan, L.K.B., and R.E. Spieler. (2006) Implications of natural variation of fish assemblages to coral reef management. Proc. 10<sup>th</sup> Int. Coral Reef Sym. 1391-1395.

### **b. Applications to management or research;**

The grunts are an extremely important component of Caribbean coral-reef ecology. The results of these studies will provide critical information for understanding and managing the distribution of juvenile grunts as well as provide insight into essential fish habitat (EFH) and required criteria for effective habitat mitigation and restoration.

**c. Data and/or information products;**

None.

**d. Partnerships established with other federal, state, or local agencies, or other research institutions (other than those already described in the original proposal).**

None.

**10. Coral Reef Mapping: From Large-Scale Morphology to Small-Scale Community Patterns (Collaborative; Continuing)**

**10.1 Work accomplishments:**

**a. A brief summary of progress, including results obtained to date, and their relationship to the general goals of the grant.**

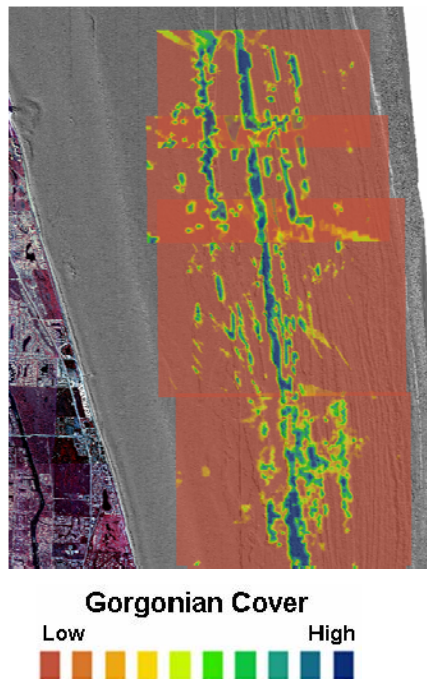
The U.S. National Action Plan for coral reef protection, endorsed by the USCRTF, identified mapping of all U.S. coral reefs as one of the highest priorities. This emphasis is continued in the National Coral Reef Action Strategy. The work being conducted by NCRI is to develop, plan, and initiate shallow-water biodiversity inventories, to perform associated biogeological assessments, and to plan a monitoring program of environmental assets of not only the nearby southeast Florida shelf reefs, but also others within U.S. jurisdiction, the project was expanded from Florida into the U.S. Caribbean.

Detailed bathymetric data for the southeast Florida reefs, from 0–100' depth were developed in previous years and served as the basemap for overlaying the results of biological and geological inventories, assessments, and monitoring. During this past year, a similar exercise was accomplished for Vieques, Puerto Rico.:

- Light detection and ranging (SHOALS-LIDAR) data taken in 2000 by the U.S. Army Corps of Engineers of the entire area surrounding Vieques. Most emphasis was put onto areas on the south coast, which had the best reef development
- AISA hyperspectral data flown over Vieques in 1999 under U.S. Navy contract.
- Aerial imagery obtained over Vieques in decadal intervals between 1937 and 2002.
- New model for the acoustic detection of biomass was developed (Fig. 1).

All data have now been pulled together in a common database and a final mapping product for Vieques and Palm Beach County, that is fully compatible and similar to previous products developed for Broward County in SE Florida, has been developed. This consists of sun-shaded bathymetric maps that detail all reef lines and associated features, which are based on LADS bathymetry. Also, fused maps consisting of hyperspectral, aerial and bathymetric information allow a “whole-system” approach

to evaluating the marine biota in relation to morphology and land-use in nearby terrestrial areas.



**Figure 1: A fused LIDAR/acoustic ground discrimination rendering of habitat and gorgonian coral biomass in Palm Beach County, Florida.**

Mapping work from Palm Beach County was successfully completed and maps consisting of sun-shaded LIDAR bathymetry overlaid with biomass estimates of reef benthos were produced (Fig. 1).

### Achievements according to the milestones:

- *Completed acoustic mapping off Broward County.*

Achieved. A total of 1200 miles of single-beam acoustic lines were obtained from Broward, Dade and Palm Beach Counties.

- *Explore various geostatistical and contouring techniques.*

Achieved. One paper that shows the use of the acoustic techniques was published in the *Journal of Sedimentary Research* and in a special issue of *The Geological Society (London)*.

- *Produce maps.*

Achieved. New maps were produced of Palm Beach, Miami-Dade, and Broward Counties and mapping products for Vieques were completed.

- b. A brief summary of work yet to be performed during the remainder of this proposed project, if changed from the original proposal.**

The project was completed successfully and the maps produced have been, or are in the process of being, circulated. Publications have been submitted.

**c. Any current problems or favorable or unusual developments.**

None. The project was concluded successfully.

**d. Provide any other significant information pertinent to the type of project support by COP.**

There is nothing unusual or significant to report.

**9.2 Specific Applications:**

**a. Publications, presentations, workshops.**

*Note:* some titles do not specifically refer to mapping, however, the study design is based on the maps, and uses and adds to the maps.

***Publication:***

Walker, B., B. Riegl, R.E. Dodge. (in press) Mapping coral reef habitats in southeast Florida using a combined-technique approach. *Journal of Coastal Research*.

**b. Applications to management or research.**

Maps previously produced have been used extensively by the local management authority (Broward County Environmental Protection Department; previously named Broward County Department of Planning and Environmental Protection), as well as by the USCRTF-tasked Southeast Florida Action Strategy Team in local action strategy (LAS) workshops. It is hoped that the maps of Vieques will be used by the new Wildlife Sanctuary. Close cooperation regarding data-sharing with the reserve management in Vieques is underway. The maps have also been used productively by NCRI researchers and by county and state management agencies in performing and for monitoring tasks.

**c. Data and/or information products.**

Metadata and original data files are available and ready to be entered into CoRIS.

**d. Partnerships established with other federal, state, or local agencies, or other research institutions (other than those already described in the original proposal).**

U.S. Department of Interior, Fish and Wildlife Services (Vieques). Additionally to mapping in Broward and Vieques, a major mapping initiative was started in the United Arab Emirates (Abu Dhabi) in collaboration with WWF and the Environmental Research and Wildlife Development Agency and proof-of-concept testing was completed in collaboration with the Centro Interdisciplinario de Ciencias Marinas in La Paz, Mexico, that resulted in two publications.

## **11. Molecular Genetic Assessment of the Relationship between Life-History Traits and Population Connectivity and Biodiversity in Coral Reef Invertebrates: Application to Marine Protected Area Design (Continuing)**

### **11.1 Work accomplishments:**

- a. A brief summary of progress, including results obtained to date, and their relationship to the general goals of the grant.**

The overall goal of this research is to fill in the substantial data gaps in our knowledge of the influence of life history traits on population connectivity in coral reef species. Towards this goal and to aid NOAA managers in ecosystem based management and conservation of coral reefs, NCRI is conducting a detailed examination of genetic population structure and biodiversity in phylogenetically diverse but heretofore poorly studied invertebrate taxa that are numerically, structurally, and ecologically important components of Caribbean coral reef communities. A specific objective is to determine if life history traits (e.g., free living vs. commensal, broadcast spawning vs. brooding/direct development) are useful predictors of dispersal potential and extent of genetic connectivity between reefs.

The taxa being investigated are two amphipod species, *Leucothoe ashlaeyi* and *L. kensleyi*, the brittle stars *Ophiothrix lineata* and *O. suensonii*, the zoanthid *Parazoanthus parasiticus*, and three sponges *Callyspongia vaginalis*, *C. plicifera*, and *Xestospongia muta*. We have been unable to find sufficient numbers of the brittle star *Ophionereis reticulata*, which was earlier proposed as a potential study species.

The two amphipods, two brittle stars, and the zoanthid are commensal with the prominent Florida and Caribbean reef sponge *Callyspongia vaginalis*. All species display contrasting reproductive life history strategies: the amphipods brood their young, the brittle stars are broadcast spawners without larvae per se (i.e., the young develop inside a fertilization membrane), the sponges are broadcast spawners with very short (<72 h) larval planktonic durations and may also reproduce by asexual fragmentation, and the zoanthid reproduces both by broadcast spawning and asexual reproduction. The vastly different reproductive life-histories of these species, overlaid on the commensal nature of some species and their occurrence in the same microhabitat (i.e., the sponge *C. vaginalis*) provide a unique opportunity to examine the influence of life-history on reef connectivity dynamics without the potentially confounding influences of different habitats that are subject to the additional environmental variables of different water circulation patterns. We have also increased our focus on sponges based on their structural and biomass importance on coral reefs, their potential as sources of pharmaceutical compounds, and the fact that there are almost no published data on their genetic (DNA-based) biodiversity and connectivity.

#### *Results to date*

The following research accomplishments have been achieved for the award performance period ending February 15, 2008:

1. A study examining detailed population genetic structure and connectivity of the two amphipods *Leucothoe kensleyi* and *L. ashleyae* and the brittle star *Ophiothrix lineata* along 355 km of the Florida reef tract (Palm Beach to Key West), and between the Florida reefs, and a relatively pristine reef in Belize (Glovers Reef) has been completed. The results of this study have been presented at two conferences and are now published in the journal *Molecular Ecology* (Richards et al. 2007). In summary, all three commensal species show extensive connectivity along the entire Florida reef tract, regardless of reproductive life history. In contrast, there is essentially no connectivity for any of the three species between the Florida reefs and Belize, even though the brittle star possesses planktonic larvae. The large expanse of deep water between the two locations appears to serve as a formidable barrier to gene flow. Of particular note is that our analyses revealed that gene flow (migration) of the brittle star *O. lineata* occurs north to south in the Keys portion of the Florida reef tract, and not south to north as might be assumed from the northerly flow of the Florida Current. This unexpected finding suggests that increased conservation and management efforts for the northern portions of the reef tract are needed to maintain the health of the southern Keys reefs. Overall, our results suggest that reproductive life history does not serve as a reliable proxy for inferring the extent of reef connectivity, and highlight the need for basing decisions of MPA design on information about connectivity derived from diverse reef inhabitants, i.e. an ecosystem based approach is needed for effective management decisions for coral reefs.

2. Our proposed examination of genetic connectivity in the two amphipod species throughout the U.S. Atlantic and the wider Caribbean is now complete. We have used DNA sequences from the mitochondrial cytochrome oxidase c subunit I (COI) gene to examine the extent of gene flow between reefs in Florida, the Bahamas, Puerto Rico, Curacao, Belize, Honduras and the Cayman Islands. Both species show an extensive degree of population structure. Statistical analysis of the DNA sequence data comparing regional Caribbean and Florida populations produced pair wise  $\Phi_{ST}$  values over 0.900, indicating highly restricted gene flow between locations. Phylogenetic analysis (Fig. 2) divided *L. ashleyae* into seven morphologically identical but genetically highly divergent lineages. The level of intraspecific divergence is among the highest reported for any marine crustacean (26% uncorrected) and exceeds that of congeners from nine diverse amphipod families. Our findings reveal multiple cryptic species endemic to Caribbean islands and that suffer from depressed levels of genetic diversity when compared to mainland Florida. Overall, the “*L. ashleyae*” populations form two major eastern and western clades: Bimini/Puerto Rico/Curacao versus Belize/Honduras/Florida.

The amphipod *Leucothoe kensleyi* appears less widely distributed in the Caribbean than its congener *L. ashleyae*. Similar genetic analyses on *L. kensleyi* from Florida, Bimini, Puerto Rico and Curacao demonstrated four genetically divergent evolutionary lineages (Fig. 2). Statistical analysis of the DNA sequence data comparing regional Caribbean and Florida populations of *L. kensleyi* produced pair wise  $\Phi_{ST}$  values over 0.900, indicating highly restricted gene flow between locations for this “species” as well. These findings indicate that *L. kensleyi* is not a single

species as described based on morphology, but is also a cryptic species complex (at least 4 cryptic species).

A manuscript describing the high levels of cryptic speciation and island endemism in these reef crustaceans is in preparation.

SEE NEXT PAGE FOR FIGURE 1

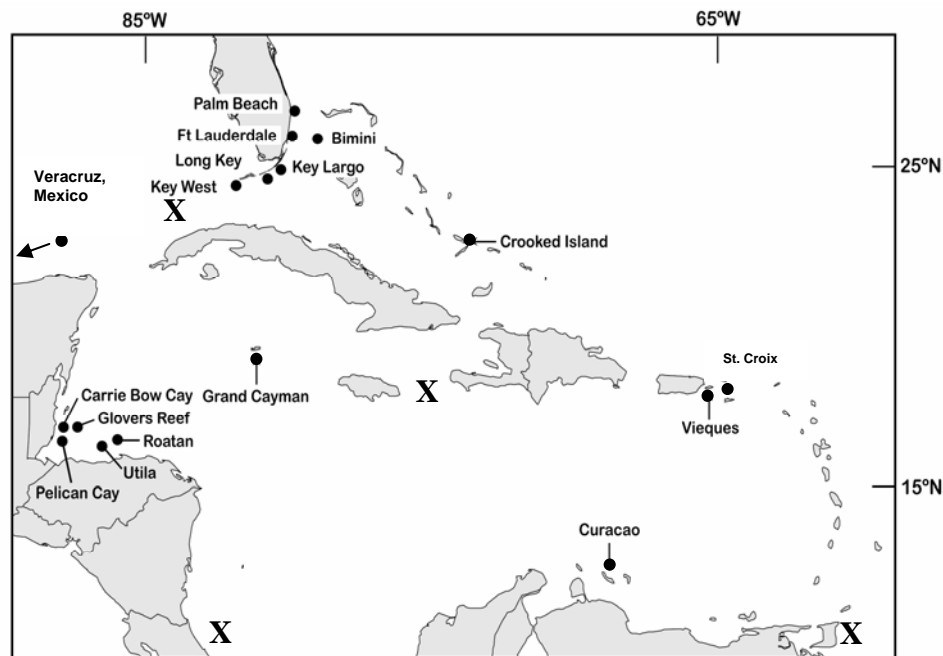
**Fig 2.** Maximum likelihood (ML) phylogram based on 414 bp of the mtDNA COI gene depicting the relationship among haplotypes. Light gray shading indicates *Leucothoe ashleyae* morphology and dark gray shading indicates *Leucothoe kensleyi* morphology. ML bootstrap values followed by Bayesian posterior probabilities are above branches. The number of individuals sharing a particular haplotype is indicated in parenthesis.



Figure 2



3. A study of the genetic connectivity of the sponge *Callyspongia vaginalis* in Florida reefs and throughout the Caribbean is now completed. Samples of this sponge have been obtained from several geographic locations (Fig. 3), and amplification and sequencing primers for the COI gene have been developed and tested. Analyses of DNA sequence data for *C. vaginalis* samples from various Caribbean locations are indicating low genetic diversity in terms of overall number of haplotypes, but highly structured populations (i.e., low connectivity between reefs) throughout the Caribbean. Gene flow estimates *within* the Florida reef tract are indicating strong connectivity between Palm Beach, Ft. Lauderdale, and Key Largo reefs, and between Long Key and Key West reefs. Notably, however, the sequence data are demonstrating a strong phylogeographic break (very low connectivity;  $\Phi_{ST} = 0.350$ ,  $P < 0.01$ ) between these northern and southern reef regions (i.e., the break occurs between Key Largo and Long Key) (Table 1). Based on this unexpected phylogeographic break, we extended our examination of connectivity dynamics to the entire length of the Florida reef tract all the way to the Marquesas and Dry Tortugas. Appropriate samples of *C. vaginalis* from these additional reef sites were collected and analyzed genetically.



**Figure 3.** Map of Florida and Caribbean Basin showing sampling sites for the sponge *Callyspongia vaginalis* and the commensal brittle star *Ophiothrix suensonii*. Filled circles indicate locations where sufficient samples for analysis have already been collected. X indicates locations where additional sampling has been conducted since the last progress report.

<b>FLORIDA REEF LOCATION</b>	Key West	Long Key	Key Largo	Port Everglades
Long Key	0.035			
Key Largo	<u>0.439</u>	<u>0.350</u>		
Port Everglades	<u>0.428</u>	<u>0.390</u>	0.046	
Palm Beach	<u>0.680</u>	<u>0.618</u>	0.084	0.134

**Table 1.** Pairwise  $\Phi_{ST}$  values for *Callyspongia vaginalis* sampled from five locations along the Florida reef tract . Underlined  $\Phi_{ST}$  values are significant ( $P < 0.001$ ) indicating strong genetic structuring (low connectivity) between these locations.

4. For the sponge *Xestospongia muta*, we have developed a microsatellite library which we are currently screening for selection of tri- and tetranucleotide microsatellites with appropriate flanking sequences for development of PCR amplification primers.
5. We are investigating connectivity among Florida and Caribbean-wide populations of the brittle star *Ophithrix suensonii* (broadcast spawner with long pelagic larval life) by using mitochondrial (COI gene sequences) and nuclear ribosomal ITS2 sequences. We have successfully developed species-specific primers for amplification of the *O. suensonii* COI gene (750 bp), and have obtained good sequences for 33 (out of the 258 collected) individuals from eight geographic locations thus far. Analysis of the 33 sequences show no indication of any population structuring (overall  $\Phi_{ST} = 0.07$ ;  $P=0.05$ ), although the number of samples sequenced is too small to draw any firm conclusions about connectivity levels. Sequencing of the remaining *O. suensonii* samples is ongoing. Development of primers for reliable ITS2 amplification and sequencing has recently been initiated; no results for this locus are yet available.

**b. A brief summary of work yet to be performed during the remainder of this proposed project, if changed from the original proposal.**

There are no changes to report.

**c. Any current problems or favorable or unusual developments.**

There are no problems or unusual developments to report.

**d. Provide any other significant information pertinent to the type of project support by COP.**

There is nothing unusual or significant to report.

## **10.2 Specific Applications:**

**a. Publications, presentations, workshops.**

The following paper was published from this project:

Richards, V.P., J.D. Thomas, M.J. Stanhope and M. Shivji. (2007) Genetic connectivity in the Florida reef system: comparative phylogeography of commensal invertebrates with contrasting reproductive strategies. *Molecular Ecology* 16:139-157.

The research described above was presented at the following conferences:

Richards, V.P., K. Feldheim and M.S. Shivji (2008). Contrasting patterns of population structure and dispersal for the giant barrel sponge (*Xestospongia muta*) within the Florida reef tract and Caribbean. Accepted for presentation at the 11<sup>th</sup> ICRS, July 7-11, 2008. Fort Lauderdale, FL.

DeBiasse, M.B. (2007) Genetic assessment of connectivity among populations of the branching vase sponge (*Callyspongia vaginalis*) in the Florida reef tract reveals a strong phylogeographic break at the Middle Keys. Florida Ecology and Evolution Symposium, April 13-15, 2007. Lake Placid, Florida, USA.

Richards, V.P., M.B. DeBiasse, M.S. Shivji (2006) Comparative phylogeography, dispersal strategy, and biodiversity in three commensal invertebrates and their host sponge. 59<sup>th</sup> Annual Gulf and Caribbean Fisheries Institute, November, 2006. Belize City, Belize. Abstract Pg. 146.

Richards, V.P., M.B. DeBiasse, M.S. Shivji. (2006) Reproductive dispersal strategy, genetic connectivity, and biodiversity among three commensal invertebrates and their host sponge. American Society of Limnology and Oceanography, Summer Meeting, July, 2006. Victoria, British Columbia, Canada. Abstract Pg. P60.

**b. Applications to management or research.**

Establishment of marine protected areas (MPAs) is widely advocated for conservation, recovery, and management of coral reef ecosystems. Selection of biologically optimal MPA sites and delineation of their spatial boundaries by the management community requires a robust understanding of the dynamics of population connectivity among reef tracts. This information is largely lacking for most U.S. reefs. To aid ecosystem based management and conservation of coral reef communities, NCRI is developing and using new molecular genetic approaches to assess dispersal potential, population connectivity, and biodiversity in a phylogenetically wide variety of reef organisms. This NCRI research is providing new, basic information to identify and understand the factors influencing reef connectivity in general. For example, our results of completed studies from three species show that the Florida reef tract appears extensively connected in terms of gene flow along the coastline (Richards et al. 2007). In contrast, preliminary results based on the sponge *C. vaginalis* are indicating a potential phylogeographic break for this species in the Florida reef tract. This finding needs confirmation (research is ongoing). With all species (brooders and broadcast spawners) that we have data for, gene flow over deep water tracts appears highly restricted, even over short geographic scales. These results show that assumptions regarding the dispersal potential of reef

invertebrates based simply on life history characteristics may be misleading and need to be empirically tested. In addition and importantly, we have discovered the existence of much greater genetic diversity (cryptic species) in some reef invertebrates, highlighting the importance of integrating traditional morphological taxonomy with new genetic techniques to reveal the full extent of coral reef biodiversity.

**c. Data and/or information products.**

All the DNA sequence data sets for three species (*L. ashleyae*, *L. kensleyi* and *O. lineata*) generated for Richards et al. (2007) have been made publicly available by posting on GenBank.

**d. Partnerships established with other federal, state, or local agencies, or other research institutions (other than those already described in the original proposal).**

NCRI researchers on this project are collaborating with researchers from the University of the Virgin Islands to sample the study species from USVI reefs. We are investigating the connectivity dynamics of reefs within the USVI, and between USVI and other Caribbean reefs.

**12. Investigations on Marginal U.S. Reef Systems: Ecology, Genetics, Propagation, and Population Dynamics of *Acropora cervicornis* off Fort Lauderdale, FL (Continuing)**

**12.1 Work Accomplishments: (as related to project objectives and schedule for completion)**

**a. Provide a brief summary of progress, including results obtained to date, and their relationship to the general goals of the grant; and**

Propagation Dynamics: In 2004 spawning activity was monitored and observed on nights 3 and 5 after the full moon of July (July 31). Release of egg-sperm bundles occurred, as expected, between 2300 and 2330h, with a high proportion of colonies (~70–80%) spawning on these nights. Spawn was collected and transported to the laboratory and self- and cross-trials were conducted. Although evidence of cleavage was observed, no motile or swimming larvae were observed by termination of the experiment (36 h after insemination).

In 2004 storm activity (Hurricanes Frances and Jean) resulted in physical damage to Acroporid corals. Community surveys indicated that in some cases live coral cover was reduced from 20 to 17% ( $p < 0.05$ , Mann-Whitney Rank Sum).

Fragmentation: In 2004 fertile fragments exhibited normal gonadal arrangement and gamete appearance (size and density).

Population genetics: In 2004 tissue samples from Thickets 1 and 3 were collected for preliminary studies on clonal structure and connectivity. Preliminary results suggest that although the Fort Lauderdale population may be composed of several different genets, each individual thicket may be dominated by one genet only. The highly

asexual nature of this population, in concert with limited recruitment suggests that population recovery after severe disturbances may be protracted.

Coral diseases: Monitoring surveys conducted in May–July 2004 indicate that although the occurrence of white-band disease (WBD) is widespread among the Broward County *A. cervicornis* population, prevalence (% of population affected) continues to be low (i.e., 1–2%). Statistical analyses indicated that WBD prevalence was not significantly different between years 2002 through 2004 ( $p > 0.05$ , Kruskal-Wallis ANOVA). A master's student is continuing this work, and a more complete report will follow as the research matures.

Histopathological studies: Most of the FY05 work centered in this area. Histopathological responses of *A. cervicornis* to increased sedimentation and phosphate enrichment were documented, with response patterns for sand proving similar to those for phosphate. The degree of stress was found to be quantifiable, using histopathological parameters. Epidermal mucocyte abundance was found to be a particularly effective indicator of stress. Findings included that stress incurred for sanded treatments was greater than that for phosphate-only treatments and that responses from different stressors were additive. Bacterial aggregates, fungi, and protests may increase in stressed tissues. Central to the theme of this project was the finding that gametogenesis is one of the first processes affected by stress.

Coral Disease and Health Consortium. NCRI continues its dialogue with the CDHC to make its resources available.

- b. Provide a brief summary of work to be performed during the next year of support, if changed from the original proposal; and indication of any current problems or favorable or unusual developments; and any other significant information pertinent to the type of project support by COP, or as specified by the terms and conditions of the grant.**

The lack of surviving embryos in our laboratory cross- and self-trials may be indicative of limited fertilization success in the field. However, suboptimal laboratory conditions may have yielded the above results. Further work in this area will be curtailed because the PI of this work, Dr. Bernardo Vargas-Angel, has moved on to work for NOAA Fisheries' Coral Reef Ecosystem Division in the Pacific. However, he continues to be in communication with other NCRI researchers and remains on the supervisory committee of the two students and their projects listed below. Additionally, Dr. Esther Peters, noted expert in coral histopathology and diseases, continues to be involved in these students' work.

## **11.2 Applications:**

- a. Publications, presentations, workshops**

### ***Publications***

Vargas-Ángel, B., S.B. Colley, S.M. Hoke, and J.D. Thomas. The reproductive seasonality and gametogenic cycle of *Acropora cervicornis* off Broward County, Florida, U.S.A. Manuscript in preparation.

Vargas-Ángel, B., S.M. Hoke, and J.D. Thomas. Fragmentation ecology in *Acropora cervicornis* in southeastern Florida: survivorship, skeletal extension, and sexual reproduction. Manuscript in preparation.

### ***Reports***

Vargas-Ángel, B. (2004) *Acropora cervicornis*: Broward County. A report for the Biological Review Team *Acropora* spp. for NOAA for possible listing of these species under the ESA.

### ***Oral presentations***

Vargas-Ángel, B. White band diseases in Broward County, FL: *Acropora cervicornis*. Prepared for the Coral Disease and Health Workshop: Developing Diagnostic Criteria, Madison, Wisconsin, April 26–29, 2004.

### ***Poster***

Hodel, E.C. and B. Vargas Ángel. (2006) Histopathological Assessment and Comparison of Sedimentation and Phosphate Stress in the Caribbean staghorn coral, *Acropora cervicornis*, 2006 Ocean Sciences Meeting, Honolulu, February 20-24.

## **b. Applications to management or research.**

NCRI's *Acropora cervicornis* research program has made significant contributions toward the evaluation of the Broward population and its reproductive potential. Our research is committed to providing effective education and dissemination of information on methods and findings related to these investigations to the general public, students, resource managers, and scientists. Studies have allowed for an assessment of species status, reproductive condition, vulnerability and resilience in the region, and established a baseline against which to compare for future change. Our research has also provided means to evaluate the potential for natural population recovery in other previously impacted *A. cervicornis* coral reef sites, and given effective advice and recommendations to local coral reef managers regarding the status of the local *A. cervicornis* population, as well as for the need for its long-term monitoring.

## **c. Data and/or information products;**

Capstone Thesis: "Histopathological Assessment and Comparison of Sediment and Phosphate Stress in the Staghorn coral, *Acropora cervicornis*," by Erin C. Hodel. (in progress).

Capstone Thesis: "White Band Syndromes in *Acropora cervicornis* off Broward County, FL: Rates of Tissue Loss and Transmissibility," by Abraham Smith. (in progress).

## **d. Partnerships established with other federal, state, or local agencies, or other research institutions (other than those already described in the original proposal).**

In addition to our original partners, the National Fish and Wildlife Foundation and Broward County, partnerships exist with the University of Miami's Rosenstiel School for Marine and Atmospheric Science as well as with the Coral Disease and Health Consortium. Collaborative work has been conducted with Florida Marine Research Institute (FMRI, Dr. Walter Jaap) to re-assess the reproductive status of *Acropora cervicornis* in South Florida from 1979 to 1981. Partnerships with Georgia Institute of Technology (Dr. Terry Snell) and Biscayne National Park are anticipated to study the RNA gene expression of stressed Acroporid corals, and reproductive status of *A. cervicornis* in Biscayne Bay, respectively.

### **13. Coral Calcification and Climate Change: Sclerochronology Analysis, Development of Data Extraction and Comparison Tools, Temperature Monitoring, and Laboratory Experimentation**

#### **13.1 Work Accomplishments: (as related to project objectives and schedule for completion)**

##### **a. Provide a brief summary of progress, including results obtained to date, and their relationship to the general goals of the grant; and**

A NCRI developed product, CoralXDS, is being used to collect physical measurements of coral extension, density, and calcification in order to expand the range and record of coral growth datasets. To date we have collected extension, density, and calcification data for 25 coral cores from the Florida Keys National Marine Sanctuary, Biscayne National Park, and Broward County, Florida using our developed methodologies. NCRI scientists have processed recently collected coral cores from Broward County and established the annual chronology back to 1694, thus this coral includes three centuries of growth and geochemical records. We have collected growth measurements of extension, density, and calcification for the past century of this 300-year record and have identified correlations between extension and density data and historical rates of freshwater discharge. We have drilled a second colony which dates back to the late 1700's. We are permitted to collect cores from two more colonies in Broward County and have chosen colonies of similar size and condition. We received samples of the deep-sea coral *Enallopsammia rostrata*, obtained in the Gulf of Mexico, and performed investigations on the presence of growth lines. The growth lines were not confirmed to be annual in nature and thus made further growth analyses unnecessary at this time. We have completed a statistical analysis of coral extension rates from 136 corals from Broward County, Biscayne Bay, and the Florida Keys. The aim of this analysis was to determine minimum sample size requirements for desired levels of correlation to be used in future coral growth sclerochronology. The results indicate that as few as 6 to 8 corals provide significant correlation with the 76 coral master chronology in Broward county and similar sample size requirements were determined for Biscayne Bay, the Florida Keys and all Florida corals combined. We have obtained coral cores from Florida Bay which will be used to measure growth parameters in relation to *in situ* water chemistry and environmental data with a focus on aragonite saturation state and

its effect on coral calcification.

- b. Provide a brief summary of work to be performed during the next year of support, if changed from the original proposal; and indication of any current problems or favorable or unusual developments; and any other significant information pertinent to the type of project support by COP, or as specified by the terms and conditions of the grant.**

In the next year of the project, NCRI researchers will continue collection of extension, density, and calcification data from newly acquired samples. NCRI researchers obtained coral cores from the Florida Bay site and will be collecting growth data in the coming year. We will continue to compare growth data of the Broward County cores with freshwater discharge data and environmental data. We will be collaborating on the collection of geochemical data with University of Miami Rosenstiel School of Marine and Atmospheric Science (UM RSMAS) and NOAA/AOML. Collection of geochemical data (carbon, oxygen, and nitrogen isotopes along with Sr/Ca, P/Ca, Ba/Ca ratios), will enable us to more specifically determine the limiting factors to coral growth associated with freshwater discharge.

## **11.2 Applications:**

### **a. Publications, presentations, workshops;**

Three publications, which have in part resulted from this work:

Banks, K.W., B.M. Riegl, V.P. Richards, B.K. Walker, K.P. Helmle, L.K.B. Jordan, M.S. Shivji, R.E. Spieler, and R.E. Dodge (2008) The reef tract of continental southeast Florida (Miami-Dade, Broward and Palm Beach Counties, USA). Springer, Dordrecht.

Smith, J.M., T.M. Quinn, K.P. Helmle, and R.B. Halley (2006) "Reproducibility of geochemical and climatic signals in the Atlantic coral *Montastraea faveolata*" *Paleoceanography*, 21, PA1010, doi:10.1029/2005PA001187.

Eakin, C.M., P.K. Swart, T.M. Quinn, K.P. Helmle, J.M. Smith, and R.E. Dodge (2006) "Application of Paleoclimatology to Coral Reef Monitoring and Management" *Proceedings of 10<sup>th</sup> Int Coral Reef Symp.* Okinawa, Japan June 28-July 2 2004, pp 588-596.

Below are oral presentations and a poster which were a direct result of work supported by this project:

K. P. Helmle, R. E. Dodge, P. K. Swart, and J. H. Hudson (2008). Coral Growth Records from Southeast Florida: A History of Anthropogenic Influence. Accepted for oral presentation at 11<sup>th</sup> ICRS, July 7-11, 2008. Ft. Lauderdale, FL.

Helmle, K.P., R.E. Dodge, and P.K. Swart (2007) Coral Growth Records and their Relationship to Freshwater Discharge in Southeast Florida. 1<sup>st</sup> Int Sclerochronology Conf., St. Petersburg, Florida, July 17-21, p43.



Helmle, K.P., R.E. Dodge, C.M. Eakin, P.K. Swart, T.M. Quinn, and J.M. Smith (2006) "Reef Building Corals as Components of Integrated Ocean Observing Systems" Eos Trans. AGU, 87(36), Ocean Sci. Meet. Suppl., Abstract OS15I-02.

Helmle, K.P. (2006) "Reef-Building Corals Respond to and Record Climate Change" Invited Speaker, Global Climate Change: Implications for South Florida's Future Conference, SFAEP, Miami Florida, Jan. 20 2006.

**b. Applications to management or research;**

Management of coral reefs under changing climatic conditions and anthropogenic impacts requires an understanding of known responses of corals to these changes. Historical coral growth and proxy records provide one means of identifying the *in situ* response of corals to past environmental changes. With enhanced understanding of how coral growth has historically responded to climate change and anthropogenic impact, managers are better equipped to make decisions about future vulnerabilities.

**c. Data and/or information products;**

The proposed investigations on coral density have so far produced 25 coral growth datasets consisting of extension, density, and calcification from massive corals of the Florida Keys, Biscayne Bay, and Broward County, Florida. Some of these datasets have been submitted to the World Data Center for Paleoclimatology, a branch of NOAA's National Climatic Data Center, and will be posted at the completion of the project. We have re-analyzed extension rate data from 136 corals in Florida and are preparing the unpublished data for submission to WDC and CORIS databases.

The CoralXDS program is freely available for download through the NCRI website: <http://www.nova.edu/ocean/coralxds/>, and links to this can also be found on NOAA's Paleoclimatology Program web page (through connections listed on <http://www.ngdc.noaa.gov/paleo/corals.html> ).

**d. Partnerships established with other federal, state, or local agencies, or other research institutions (other than those already described in the original proposal).**

We are collaborating with Dr. Peter Swart at the UM RSMAS in coring corals from Florida Bay and the Florida Keys. Support has also been provided by NOAA, NESDIS National Climatic Data Center, through collaboration with Dr. C. Mark Eakin addressing application of paleoclimatology to monitoring areas of management concern. We have completed a collaboration with Dr. Harry Roberts of LSU and others as part of a deep sea cruise aimed at defining benthic communities below 1000 meters.

**14. Additional New Project: Scientific Review, Compilation, and Assessment of Coral Spawning Time in the Atlantic/Caribbean**

**14.1 Work Accomplishments: (as related to project objectives and schedule for**

completion)

- a. Provide a brief summary of progress, including results obtained to date, and their relationship to the general goals of the grant;**

A review of existing scientific literature (121 article total) regarding Atlantic and Caribbean coral reproduction and recruitment of scleractinian corals was undertaken. Articles were reviewed, annotated, and entered into EndNote, a searchable bibliographic program. Each article was listed with the following information: Author, Year, Title, Journal, Volume, Pages, Location, Type of work, and Keywords.

Applicable information from each article was also entered into Excel. Data were compiled in a user friendly and searchable table that includes information on each coral species in regards to mode of reproduction, cited literature sources, location of research, spawning times, method of observation, environmental factors affecting spawning, and duration of larvae in the water column.

Family	Taxa	Sex	Reproduction Mode	Article Source	Location of Work	Time of Spawning	Method of Observation	Environmental Factors Linked to Spawning	Duration in Water Column
11 included	64 included	Gonochoric (male/female), Hermaphroditic, or Mixed	Broadcast or Brooding	Author(s) & Year	Atlantic/ Caribbean	Lunar time, time of day, etc.	Field, Laboratory or Histological	Temperature, Tides, Seasonality, etc.	Time period before settlement

Eleven families and 64 taxa of corals are included in the table. Thirty-three of the 64 taxa are without any applicable coral spawning research. An estimate range of sensitivities or a “sensitivity window” for the reproduction and recruitment of each coral species can be determined using the information provided in the table as well as the lunar calendar for upcoming years to make extended predictions.

- b. Provide a brief summary of work to be performed during the next year of support, if changed from the original proposal; and indication of any current problems or favorable or unusual developments; and any other significant information pertinent to the type of project support by COP, or as specified by the terms and conditions of the grant.**

Data collection has been completed for this project as funded.

#### **14.2 Applications:**

- a. Publications, presentations, workshops;**

This project was presented at the Coral Reef Task Force Meeting in the Virgin Islands in October 2006. The results are also posted on the NCRI website and will be posted to the U.S. Coral Reef Task Force webpage under the “Coral Spawning Working Group” link. Findings will also be individually distributed to managers throughout the Caribbean

**b. Applications to management or research;**

This project was performed to provide information to managers throughout the Caribbean to help them reduce human impacts during the critical coral spawning window. Modification of the type or timing of activities that introduce nutrients, toxic chemicals, and suspended particles may lead to enhanced fertilization and coral recruitment success. For many of the main reef-building species, information on coral spawning times is known and can be predicted. However, in most locations this information has not been widely available or previously considered during planning and implementation of human activities. Compilation of this information by species and by region will give managers the information they need to help protect corals during a sensitive phase of their life history.

**c. Data and/or information products;**

- a. Excel table of coral spawning information
- b. Searchable EndNote database of applicable research
- c. Annotated citations of each research article
- d. Lunar calendar for extended predictions

**d. Partnerships established with other federal, state, or local agencies, or other research institutions (other than those already described in the original proposal).**

NCRI's partnership with NOAA's National Centers for Coastal Ocean Science (NCCOS) continues.

**15. Additional New Project: Enhancement of Restoration Techniques for *in situ* Seeding of Coral Larvae on Denuded Substrate (External project; PI Diego Lirman, Ph.D., University of Miami)**

**15.1 Work Accomplishments: (as related to project objectives and schedule for completion)**

**a. Provide a brief summary of progress, including results obtained to date, and their relationship to the general goals of the grant; and**

For degraded reef systems with low natural recruitment, active restoration techniques to seed larvae directly onto the reef may provide the impetus to replenish adult stocks. However, *in situ* seeding techniques have only been attempted in a handful of studies, and many questions remain regarding the usefulness of these approaches. The goals of this study were to assess the efficacy of seeding larvae directly onto denuded reef substrate and explore techniques to improve the success of this active seeding strategy. In addition, this study compared the success of this direct *in situ* seeding approach to an *ex situ* seeding approach where larvae were settled onto small substrate chips, reared in the laboratory for four months, and then transplanted onto the reef. Overall, survivorship of *in situ* seeded larvae typically followed an

exponential decline with less than 10% surviving after 15 days. For some of the newly settled larvae, their survival significantly improved when potential predators were excluded by cages and as the density of initial settlers increased. In addition, the general substrate type on which they settled had a significant effect on their survival. Comparatively, those larvae settled in the lab and then transplanted to the reef at four months of age had a markedly higher survival rate than those individuals settled directly on the reef. Although more research is needed on direct seeding techniques, we conclude that transplanting older individuals settled *ex situ* is a more effective technique for artificially increasing recruitment on a reef.

- b. Provide a brief summary of work to be performed during the next year of support, if changed from the original proposal; and indication of any current problems or favorable or unusual developments; and any other significant information pertinent to the type of project support by COP, or as specified by the terms and conditions of the grant.**

None

## **15.2 Applications:**

- a. Publications, presentations, workshops;**

### ***Publications:***

Cooper, W, D. Lirman, M. Schmale, and D. Lipscomb. (2007) Consumption of coral spat by histophagic ciliates. Coral Reefs 26: 249-250.

### ***Presentations:***

Cooper, W.T. (2007) Quantifying the *in situ* survivorship of recently settled coral spat. Presentation to the AAUS 2007 Annual Symposium. Miami, Florida.

- b. Applications to management or research;**

This study was designed to assess the efficacy of seeding larvae directly onto denuded areas of a reef, and to explore techniques for improving the success of these seeding strategies for restoration applications. Overall, the survival of newly settled *Porites astreoides* spat was low, with less than 10% of the individuals surviving after 15 days and less than 1% after 6 months. Despite potential increases in survivorship through the use of cages, appropriate selection of substrate, or substrate modifications, the magnitude of the increase in survival was usually only 5-10%, and recruitment success was minimal. Unless higher larval stocks can be easily obtained or alternative enhancement strategies can be found to improve survival, the high rates of mortality in newly settled coral larvae may limit the effectiveness of *in situ* seeding strategies. However, it is important to note that this study was performed at only one reef site and under relatively exposed conditions where larvae were settled only onto upward-facing substrates. These exposed microhabitats were chosen to represent habitats typical of those requiring active restoration, such as denuded areas left from a vessel grounding or artificial substrate from structural repair. Given this small range of microhabitat conditions used in this study, the potential exists for higher

survivorship for other microhabitat conditions (e.g., vertical or downward-facing orientations, characteristic of higher topographic complexity).

Comparatively, when larvae were settled onto small substrate chips, reared in laboratory conditions for four months, and then transplanted on the reef, survival rates increased by up to 50% after one month. As a restoration technique, such *ex situ* seeding with later transplantation may be the most cost-effective and efficient approach to maximize the survival of limited larval stocks. In addition, collection and settlement of larvae in laboratory conditions are not dependent on weather conditions which can often limit the ability to either collect or seed larvae on critical days when adults are spawning or larvae are competent and ready to settle. In conclusion, until a successful *in situ* approach is developed with high and repeatable recruitment success, *ex situ* settlement approaches may provide the most effective use of larvae when attempting to artificially increase coral recruitment.

**c. Data and/or information products;**

None

**d. Partnerships established with other federal, state, or local agencies, or other research institutions (other than those already described in the original proposal).**

None

**16. Additional New Project: Fine-Scale Genetic Structure of Scleractinian Corals and Implications for Reef Restoration (External project; PIs: Terry Snell, Ph.D./Tonya Shearer, Ph.D., Georgia Institute of Technology)**

**16.1 Work Accomplishments: (as related to project objectives and schedule for completion)**

**a. Provide a brief summary of progress, including results obtained to date, and their relationship to the general goals of the grant; and**

To date, ~80% of coral samples have been collected, DNA has been extracted/purified/quantified and microsatellite analyses are currently underway. The results from the microsatellite analyses will indicate whether gene flow is occurring among populations at three depths within Conch Reef, FL. We are also testing novel primers for additional microsatellite loci for each species in order to generate additional data for genetic analyses.

**b. Provide a brief summary of work to be performed during the next year of support, if changed from the original proposal; and indication of any current problems or favorable or unusual developments; and any other significant information pertinent to the type of project support by COP, or as specified by the terms and conditions of the grant.**

Our sampling trips were canceled and hampered by bad weather, so samples were collected later than expected. We also need to make another trip to finish collections.

An additional trip is necessary to complete collections for this study. These samples will be analyzed upon return from the field. New loci generated in this study will be screened for all samples collected in this study and those collected from previous studies.

## **16.2 Applications:**

### **a. Publications, presentations, workshops;**

#### ***Presentations:***

Seminar at Auburn University (Alabama) Biology Department, “Biological connectivity among Caribbean reefs” – T. Shearer.

Seminar at Berry College (Georgia) Biology Department, “Biological connectivity among Caribbean reefs” – T. Shearer.

Workshop (hosted at Georgia Institute of Technology by T. Shearer, to be held in March 2006): Coral Connectivity Working Group - The Coral Reef Targeted Research & Capacity Building for Management Project.

### **b. Applications to management or research;**

Once analysis is complete, information on gene flow and larval dispersal will be used to assess small-scale levels of connectivity which is pertinent to management of reef resources (establishment and success of MPAs) and also assess potential recovery rates of populations after disturbance.

### **c. Data and/or information products;**

None at this time.

### **d. Partnerships established with other federal, state, or local agencies, or other research institutions (other than those already described in the original proposal).**

Continuing partnerships with University at Buffalo (M. Coffroth) and Rosenstiel School of Atmospheric Science (D. Swanson, J. Ault). New association with the University of the United Nations (Coral Connectivity Working Group - The Coral Reef Targeted Research & Capacity Building for Management Project). Also developing research relationship with Georgia Aquarium.

## **17. Conferences and USCRTEF Related Activities (Continuing)**

### **17.1 Work Accomplishments: (as related to project objectives and schedule for completion)**

#### **a. Provide a brief summary of progress, including results obtained to date, and their relationship to the general goals of the grant; and**

NCRI provided leadership and impetus to organize a successful bid for the U.S. to

host the 11<sup>th</sup> International Coral Reef Symposium (ICRS) in Fort Lauderdale in July of 2008. A series of International Society for Reef Studies (ISRS) Selection Committee requirements were met in a detailed Expression of Interest, leading to the selection of the United States as one of three finalists. A U.S. team, lead by NCRI Executive Director Richard E. Dodge, made the winning presentation, albeit with considerable passion supplied by team members from the Florida Institute of Oceanography, the Florida Institute of Technology, the State of Florida, and NOAA. Before pursuing the bid, endorsement was sought and received from the U.S. Coral Reef Task Force and the State of Florida. Former Governor Jeb Bush and NOAA Deputy Assistant Secretary for Oceans and Atmosphere, Timothy R.E. Keeney, co-chair of the United States Coral Reef Task Force (USCRTF), both wrote letters of support to the President of ISRS and the Chair of the Selection Committee. Announcement of the U.S. win to host the 2008 meeting was made at the 10<sup>th</sup> ICRS in Okinawa in early July 2004.

The Initial Organizing Committee that initiated the U.S. bid has formed the Local Organizing Committee (LOC). Chairs of the major committees have been named and a plan of work adopted.

The nature of the science program has been defined and the contract for producing the Proceedings has been finalized.

Among the ISRS requirements for the meeting is the employment of a firm to act as the professional meeting organizer to oversee the coordination of all aspects of the meeting. Through an RFP and evaluation process, the LOC has chosen the Federation of American Societies for Experimental Biology (FASEB) Office of Scientific Meetings and Conferences. FASEB will manage the meeting venue, scientific meeting, exhibits, publications, ancillary events, the registrations, and all financial operations to include subcontracting. FASEB has extensive experience in such meetings and is a respected resource for large meeting budgets, as well managing meeting finances, through sponsorships, grants, and exhibit revenue, in addition to attendee registrations. FASEB staff members have already undertaken other ICRS tasks, such as working with a designer to develop a logo and the printing and mailing of the first circular, which went out in fall 2006 and the second circular, which was distributed in August 2007. Initial planning for the NGO and commercial exhibits has also begun with input from both the Exhibits Subcommittee Chair and the FASEB staff and exhibitors have been finalized.

The Call for Abstracts went out in August 2007 and there were over 2300 abstracts submitted. Abstracts were accepted in February 2008 for approximately 900 oral presentations and 1400 poster presentations. Plenary speakers have been confirmed.

The LOC has been holding monthly conference calls since mid-2005 and three site visits of the LOC have been held in order to plan this 2008 meeting. Milestones and a timeline have been set and met.

A limited-access website has been set up for members of the LOC. Meeting agendas, meeting minutes, and other documents of interest and for use by members of the LOC are posted on the website for easy downloading and enhanced communication.

The official 11th ICRS website has also been created and is currently active and is updated as new information is finalized and made available. The scientific schedule is available.

Additionally, NCRI continues to support the activities of the USCRTF local action strategy (LAS) of southeast Florida, Southeast Florida Action Strategy Team (SEFAST), now called the Southeast Florida Coral Reef Initiative (SEFCRI). NCRI often logistically supports meetings of the SEFCRI teams, including the bi-annual Land-Based Source Pollution Technical Advisory Committee meeting and provides active membership on three of the four SEFCRI focus groups.

Working with SEFCRI, NCRI researchers also continue to map the fragile coral reefs of southeast Florida. Having already successfully mapped the benthic habitats of Broward and Palm Beach Counties, NCRI has begun the mapping of Miami-Dade coral reefs with funding through Florida DEP CRCP and both LIDAR and habitat mapping are in the planning stages for Martin County, FL through a recent award from the State of Florida's Wildlife Legacy Initiative Grant.

NCRI mapping research played an integral part in the recent reconfiguration of the Port Everglades commercial ship anchorage in Broward County, FL. The modifications were made after a review of commercial vessel groundings and in an effort to protect fragile living coral reef areas adjacent to current anchorage locations. The NSU OC and NCRI are both represented on the Port Everglades Harbor Safety Committee, which is chaired by the Coast Guard Sector Miami and includes representation from federal, state and county agencies, and local maritime and environmental stakeholders. The reconfiguration was a partnership effort among all the stakeholders and represents a joint effort to both preserve the anchorage function and to protect the invaluable reef resources. NCRI researchers were particularly instrumental in providing GIS-based images of recent ship groundings associated with the anchorage and coral reef habitats and GIS analyses to optimize the anchorage reconfiguration for all stakeholder interests and will soon be under contract with Florida DEP CRCP to evaluate the status of two other major ports in southeast Florida, the ports of Miami and Palm Beach. The benthic habitat maps will be a key component in the GIS to evaluate the coral reef's proximity to these major port anchorages. If necessary, modifications will be proposed to reduce ship anchoring impacts and help protect the coral reefs.

Finally, NCRI participates in the USCRTF meetings, having attended all the meetings since the 1998 inception. NCRI also has informational booths at the USCRTF, providing NCRI research dissemination to the USCRTF members and other constituents. For the last two years, NCRI has also used the USCRTF meetings to promote the 11<sup>th</sup> ICRS. NCRI Executive Director and 11<sup>th</sup> ICRS LOC Chair, Dr. Richard Dodge has been invited to present the outcomes of the 11<sup>th</sup> ICRS at the 20<sup>th</sup> meeting of the USCRTF in August 2008 in Kona, HI.

- b. Provide a brief summary of work to be performed during the next year of support, if changed from the original proposal; and indication of any current**



**problems or favorable or unusual developments; and any other significant information pertinent to the type of project support by COP, or as specified by the terms and conditions of the grant.**

The planning for the 11<sup>th</sup> ICRS is almost complete. Monthly teleconferences are planned to continue in order to move forward in a timely manner and an additional site visit took place in April 2008. An issue of considerable importance is securing sufficient financial support to put on a first-class meeting that will meet expectations. Funding has been secured from many NGOs and corporate sponsors and last minute donors are still being courted. Major sponsorships must be secured in order to meet the \$1.25 million shortfall. NOAA has provided to date \$149,000 in funding, and other USCRTF agencies have contributed, including \$160,000 from DOI and the U.S. Coast Guard. As the 11<sup>th</sup> ICRS approaches, the expenses are dependent on actual attendee numbers and funds will be allocated according to need.

NCRI researchers and staff will continue to work closely with SEFCRI by contributing to SEFCRI Technical Advisory Committees and Organizational Committees, by hosting workshops and meetings with SEFCRI, in local mapping projects and in any other partnerships which might arise.

NCRI will also continue to participate in the bi-annual meetings of the USCRTF and to participate on the USCRTF Education and Outreach Committee.

## **17.2 Applications:**

### **a. Publications, presentations, workshops;**

Dr. Dodge has made a number of presentations about the 11<sup>th</sup> ICRS, including one to a group of NGOs, hosted by the United Nations Foundation in Washington, DC, in early February 2006. Additionally, NOAA's Roger Griffis gave a presentation on NCRI's behalf about the 11<sup>th</sup> ICRS at a USCRTF meeting, and a presentation was also made at the meeting of the International Coral Reef Initiative (ICRI) meeting that preceded it in Palau. Dr. Dodge also presented at the Washington DC ICRI meeting in January 2008 and at the International Year of the Reef launch which took place after the ICRI meeting. Dr. Dodge also made a presentation at the 16th USCRTF meeting in October 2006 in St. Thomas, asking agencies for their support of the 11<sup>th</sup> ICRS and a resolution as passed to "Support planning and implementation of the 2008 International Coral Reef Symposium", reaffirming its support and endorsement of the 2008 ICRS and requesting members to consider participation and funding (consistent with legal authorities) to help support development and implementation of the U.S.-hosted symposium. Dr. Dodge presented the 11<sup>th</sup> ICRS at the 17<sup>th</sup> USCRTF meeting in early March 2007 and the 18<sup>th</sup> USCRTF in American Samoa. Wendy Wood, NCRI administrative coordinator, presented for the public comment section of the 19<sup>th</sup> USCRTF in February 2008.

The 11<sup>th</sup> ICRS Second Circular was distributed in August 2007 and an exhibits prospectus was made available later in 2007. The Abstract Book and 11<sup>th</sup> ICRS Program Book are currently being printed and a Proceedings publication is being

organized by NCRI Associate Director Bernhard Riegl.

**b. Applications to management or research;**

Only by sharing the latest and best scientific information can resource managers protect and conserve coral reefs and their associated habitats. These ecosystems are connected regionally and globally, so information must be shared thusly. Through the 11<sup>th</sup> ICRS, NCRI is supporting the dissemination of the best science, leading to best management tools and continued research for coral reefs locally, nationally and globally.

Through conferences and meetings, NCRI serves the management goals of USCRTF and SEFCRI/SEFAST.

**c. Data and/or information products;**

None.

**d. Partnerships established with other federal, state, or local agencies, or other research institutions (other than those already described in the original proposal).**

In addition to the partnerships already formalized with the International Society for Reef Studies, the Florida Institute of Oceanography, the Florida Institute of Technology, University of Miami's NCORE at RSMAS, the University of Georgia, the Florida Keys Marine Sanctuary, the University of South Florida, NOAA, Department of Interior, USGS, the U.S. State Department, the University of Hawaii, and the State of Florida, several others have taken place or are in process. These include the Federation of American Societies of Experimental Biology (FASEB); the Ocean Foundation; Florida's Protect Our Reefs license plate program and its administrator, Mote Marine Labs; and the Khaled bin Sultan Living Oceans Foundation. Also joining in the last year are the World Bank, the Florida Fish and Wildlife Research Institute, the Herbert W. Hoover Foundation, the David & Lucile Packard Foundation, the Nature Conservancy, the Summit Fund of Washington, The Living Oceans Foundation, the Guy Harvey Research Institute and the World Wildlife Fund.

## **18. The NCRI Fellowship**

### **18.1 Work Accomplishments: (as related to project objectives and schedule for completion)**

**a. Provide a brief summary of progress, including results obtained to date, and their relationship to the general goals of the grant; and**

In order to broaden the impact of research and scholarship at NCRI, it was decided to support promising students with a fellowship in support of studies compatible with

NCRI's goals. These scholarships allow students to embark on, or to finish research that is considered to be within NCRI's framework of objectives.

During this second year, the fellow continued work on the joint KBSLOF/NCRI Fellowship. In collaboration with the Khaled bin Sultan Living Oceans Foundation, it was possible to increase the award amount, to make this fellowship (now called the NCRI/KBSLOF Fellowship) a multi-year award geared towards doctoral studies. This allows more efficient use of funds and did not increase the cost to NCRI but has the potential of greatly increasing the benefits. With the support of KBSLOF, the fellow took part in two more expeditions in the Red Sea and obtained large amounts of satellite imagery for work on a Ph.D. thesis. The fellow also continued a close collaboration with the University of Cambridge in the UK. The fellow also published his first publication (Rowlands et al, Journal of Spatial Research, 2008) which is a product of the NCRI Monitoring Network.

Success according to the milestones:

- *Award first fellowship.*

Achieved in 2006.

- *Support and supervise NCRI fellow.*

NCRI/KBSLOF fellow is presently working towards Ph.D. degree under the supervision of Drs. Purkis and Riegl.

- *Evaluate NCRI fellow and efficacy of program.*

So far, the work of the NCRI/KBSLOF fellow has contributed to two manuscripts that have been submitted to publication. Therefore, the program is considered efficient.

- *Prepare and publish call for applications, unless fellow will be retained.*

Not necessary at this stage since the fellow has another three years to go.

- b. Provide a brief summary of work to be performed during the next year of support, if changed from the original proposal; and indication of any current problems or favorable or unusual developments; and any other significant information pertinent to the type of project support by COP, or as specified by the terms and conditions of the grant.**

Fellow will proceed to publish work done with satellite and airborne multispectral imagery to characterize habitats in the Red Sea. He will proceed to work on hyperspectral imagery made available by KBSLOF to characterize ecosystem state in Red Sea coral reefs.

## **18.2 Applications:**

- a. Publications, presentations, workshops;**

Gwilym P. Rowlands, S.J. Purkis, and B.M. Riegl (2008). CASI mapping of the Farasan Islands (Saudi Arabia): Ecosystem processes in an atypical Red Sea

setting. Accepted for oral presentation at the 11<sup>th</sup> ICRS, July 7-11, 2008. Ft. Lauderdale, FL.

Rowlands, G, S.J. Purkis, B. Riegl (2008) Use of pseudo-invariant features (PIFs) to detect coral bleaching in satellite images. Journal of Spatial Research (in press).

**b. Applications to management or research;**

The provision of a fellowship provides selected, particularly promising persons the time and resources to embark on, or to finish research projects. Since these have to be within NCRI's framework of objectives, the fellowship provides research that is applicable to management.

**c. Data and/or information products;**

Not applicable.

**d. Partnerships established with other federal, state, or local agencies, or other research institutions (other than those already described in the original proposal).**

Not applicable.